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SEWAGE WORKS JOURNAL

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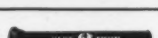

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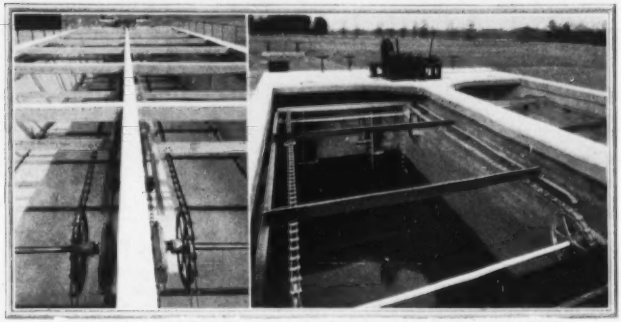

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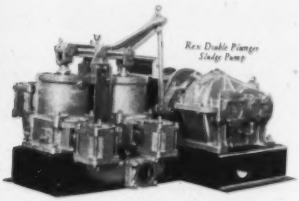

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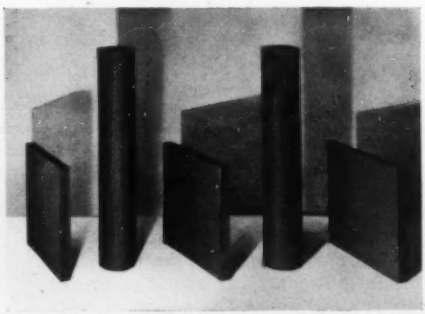

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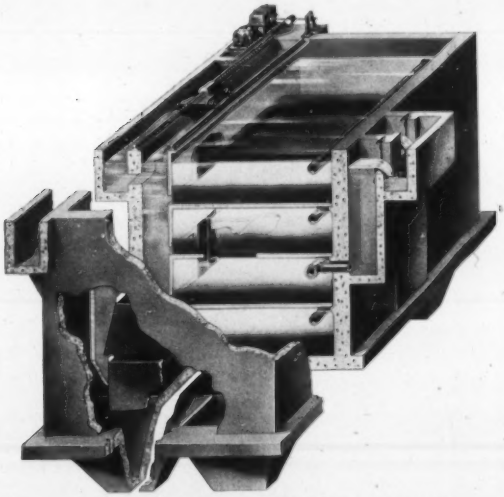

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Sewage Research

The Dewatering of Sludge by Vacuum Filtration

By C. E. Keefer and E. C. Cromwell

Principal Assistant Engineer and Principal Sanitary Chemist, Bureau of Sewers, Baltimore, Md.

For many years the sanitary engineer has been endeavoring to find some mechanical means of satisfactorily and economically dewatering digested sludge from Imhoff or separate digestion tanks. Such devices have been experimented with, and in a few instances they have been used. The difficulties encountered, however, have been such that the drying of sludge on either open or covered beds has been almost universal. This latter method of sludge dewatering has been practiced for many years. In spite of the great advances made in sewage treatment during the past decade, the air drying of digested sludge still remains unchanged. Such is the case even though the method has many disadvantages such as the possibility of producing odors and its dependence on climatic conditions.

The successful drying of activated sludge for a number of years by vacuum filtration indicated that this method might be applicable to dewatering digested material from separate sludge-digestion tanks. Two experimental filters were, therefore, installed at Baltimore, one made by the Bartlett-Hayward Co., called a Genter filter, and the other by the Oliver United Filters, Inc. A series of experiments was conducted, using these two machines and filtering material from the same digestion tanks. Both filters were found capable of satisfactorily dewatering digested sludge. The capacities of the two machines increased with the use of larger quantities of coagulant. A maximum output of approximately 20 lb. of dry solids per square foot of filter area per hour was obtained when using a Genter filter and coagulating the sludge with $10^1/_2$ lb. of ferric chloride per 100 lb. of dry solids. The Oliver filter produced a maximum output of about 18 lb. of dry solids when using 12 lb. of ferric chloride per 100 lb. of dry material. It should be pointed out that the sludge dewatered by the Oliver filter when using large quantities of ferric chloride was different from the material handled by the Genter machine, and was also harder to filter. When dewatering the same sludge with all other conditions alike, it is believed that the capacities of the two filters should be about the same.

Three estimates have been prepared covering the cost of filtration. The

estimates are based on dewatering digested sludge at Baltimore, amounting to 60,000 lb. of dry solids daily. The costs vary from $4.22 to $5.00 per ton of dry solids, depending upon the quantity of coagulant used and the nature of the digested sludge to be dewatered. The average cost of air-drying sludge at Baltimore for the years 1925 to 1931, inclusive, was $6.23 per ton of dry solids, or 24 per cent higher than when using vacuum filtration at a cost of $5.00 per ton.

Sludges Filtered

Most of the experimental work consisted in dewatering digested sludge. The solids collected at the Baltimore sewage works are from a separate system of sewers, which receive comparatively little industrial wastes. The raw sewage flows through coarse racks with $^{7}/_{8}$-in. clear openings, and then enters sedimentation tanks with a detention period of about 2 hrs. These tanks are cleaned every 5 or 6 days. The raw sludge removed is far from fresh, as is indicated by its pH value, which is about 4.9.

This material is pumped into one or more of the digestion tanks, of which there are 49. The tank from which the ripe sludge used in these experiments was drawn is a small unit with a capacity of 20,600 cu. ft. The tank is heated by means of hot water pipe coils. The temperature of the digested sludge as drawn varied from a minimum of 63° to a maximum of 89° F. It is estimated that the digestion period averaged 50 days. The ripe sludge contained from 4.8 to 9.9 per cent dry solids, 51.5 to 61.1 per cent volatile matter, with pH values varying from 6.6 to 7.0. The material usually contained sufficient fibrous substances to give it excellent filtering characteristics.

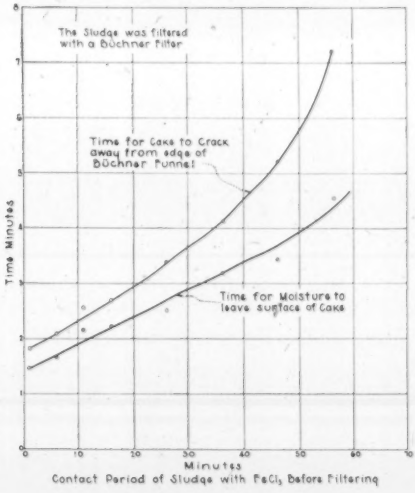
Although most of the studies were concentrated on dewatering digested sludge, some work was also done on filtering semi-digested material. These solids were drawn from another of the digestion tanks at the sewage works. This tank, however, was unheated. The pH value of the material varied from 6.3 to 6.9, the dry solids from 5.6 to 7.9 per cent, the volatile solids from 61.0 to 64.5 per cent and the temperature from 51° to 75° F.

Some tests of short duration were made dewatering raw sludge. Although the exact age of the material is not known, it is apparent from the volatile matter content, which varied from 71.2 to 78.8 per cent that the sludge was undigested. The pH value fluctuated from 4.6 to 5.5, the solids from 2.3 to 7.7 per cent and the temperature from 68° to 79° F.

Although it is sometimes difficult to distinguish between a digested and a semi-digested sludge by determining the volatile matter content, it has been observed that well-digested sludge at Baltimore generally contains about 55 per cent or less volatile matter. The volatile matter in the raw

sludge is usually about 75 to 78 per cent with a maximum of about 85 per cent.

Coagulating Tanks.—Between the digestion tank and each filter there were two coagulating tanks, into which the sludge flowed before passing to the filters. The two tanks serving the Genter filter were each 5 ft. deep, 3 ft. in diameter, and were provided with paddles attached to a vertical shaft for mixing the sludge and the coagulant. The two tanks into which the sludge flowing to the Oliver filter was coagulated were of


The Sludge was filtered with a Büchner Filter
Time for Cake to Crack away from edge of Büchner Funnel
Time for Moisture to leave surface of Cake
Time Minutes
Minutes
Contact Period of Sludge with FeCl3 before Filtering

EFFECT OF PERIOD OF CONTACT OF $FeCl_3$ AND DIGESTED SLUDGE ON TIME OF FILTRATION

FIG. 1.

the same general construction but slightly larger. Two stationary wooden strips were set in a horizontal position diametrically across each of the tanks near the bottom. The mixing in these tanks was more vigorous than in those serving the Genter filter. The purpose of using two tanks was to make the dewatering process continuous. While conditioned sludge was drawn from one, another batch of material was prepared in the other. This latter operation consisted of stirring the sludge for 5 minutes to give it a uniform consistency. A sample was then collected for subsequent analysis, and the conditioner added.

TABLE I

DIGESTED SLUDGE DEWATERED WITH A GENTER FILTER

(Coagulant: $FeCl_3$. Tests made April 4 to June 18, 1932)

Test No.	Duration of Test, Hrs.	Sludge Added: Solid Content, %	Sludge Added: Volatile Matter, %	Sludge Added: pH	Temperature, ° F.	Anhydrous $FeCl_3$ Used per 100 Lb. Dry Solids, Lb.	Cake: Moisture, %	Cake: Dry Cake per Sq. Ft. of Filter Area per Hr., Lb.	Cake: Thickness, In.	Effluent: Suspended Solids, P. p. m.	Effluent: pH	Filter Operation: Speed, Sec. per Rev.	Filter Operation: Oscillations per Min.	Filter Operation: Vacuum, In.
1	3.5	5.4	59.6	6.8	65	7.88	76.8	13.9	..	322	5.1	102	20	25
2	3.5	5.0	59.3	6.8	65	8.21	76.4	12.5	..	336	5.4	102	20	19–24
3	3.5	5.5	58.8	6.9	68	8.34	78.4	16.4	..	242	5.3	96	15	21–24
4	3.5	5.8	60.9	6.9	68	8.31	76.4	16.4	..	340	5.3	96	15	18–24
5	2.5	6.5	60.4	6.8	66	6.60	74.9	16.7	..	356	5.1	96	15	22–23
6	3.5	5.3	59.9	6.9	63	7.47	75.4	15.4	..	358	5.5	96	15	20–23
7	3.5	5.2	60.2	6.9	64	7.24	75.7	14.0	..	385	6.0	96	15	22–25
8	3.5	5.2	60.2	6.6	65	6.81	76.7	12.2	..	365	5.9	96	15	20–25
9	3	5.0	61.0	6.7	66	7.15	77.1	10.5	..	361	6.4	102	15	20
10	3.5	5.2	61.1	6.8	65	7.01	76.3	10.5	..	379	6.3	120	15	24
11	3	5.4	60.5	6.8	65	6.10	75.9	7.8	..	501	6.5	180	15	23–24
12	3.5	5.8	60.2	6.7	64	5.82	77.1	9.4	..	560	6.3	150	15	21–24
13	3	6.0	59.3	6.7	63	4.63	75.3	9.3	..	621	6.5	150	15	21–25
14	3	5.6	59.5	6.7	64	4.92	75.7	7.4	..	736	6.6	150	30	7–21
15	3	6.0	60.3	6.8	66	4.29	75.8	7.3	..	683	6.5	150	15–20	18–26
16	3	5.6	59.5	6.8	66	4.47	75.5	6.2	..	951	6.5	150	15	22
17	3	6.0	59.5	6.8	69	4.10	76.1	6.2	..	677	6.4	180	15–20	11–26
18	3	5.6	59.2	6.8	67	4.33	76.1	4.4	..	824	6.4	240	15	21
19	3	5.4	58.2	6.8	71	3.54	76.8	2.9	..	781	6.6	300	15	12–23
20	3	5.1	59.3	6.8	71	5.94	78.1	7.7	..	462	6.5	150	15	22–25
21	2	5.5	59.2	6.7	73	7.61	75.9	14.5	..	359	6.1	96	15	10–25
22	2	4.9	58.8	6.7	73	7.93	76.2	14.0	..	348	6.1	96	15	8–23
23	2	4.8	58.6	6.9	74	7.27	76.7	12.0	..	432	6.3	96	15	17–23
24	2	5.0	58.1	6.9	74	8.36	77.3	15.9	..	259	6.1	96	15	7–23
25	2	5.2	57.9	6.9	76	7.27	77.8	12.5	..	378	6.2	96	15	9–18

26	2	5.3	58.3	6.9	76	6.02	78.2	10.7	..	495	6.6	96	15	5–23
27	2	5.3	58.8	6.9	74	5.69	77.7	5.5	..	692	6.7	180	15	8–24
28	2	5.4	59.0	6.9	77	5.57	78.4	5.5	..	704	6.7	180	15	6–24
29	1	5.4	58.8	6.9	77	3.73	78.6	2.1	..	1153	6.9	360	15	8–26
30	2	5.7	58.3	6.9	78	6.26	77.9	10.9	..	479	6.5	102	15	5–23
31	1	5.4	58.6	7.0	79	6.08	78.5	9.8	..	533	6.7	102	15	7–23
32	2	5.4	58.6	7.0	79	6.15	78.3	7.1	..	592	6.7	150	15	6–25
33	1	6.1	57.6	6.9	79	5.19	80.5	5.8	..	1014	6.5	150	15	24
34	2	6.1	57.4	6.9	79	4.85	78.3	5.4	..	770	6.6	180	15	15–25
35	1	5.5	57.6	6.9	79	5.37	77.2	5.7	..	1300	6.5	180	15	22
36	14	5.8	57.6	6.9	77	5.54	75.7	6.8	0.21	574	6.7	180	15	18–25
37	2	5.9	56.2	6.9	88	9.16	76.3	18.1	0.31	388	6.1	96	15	24
38	2	5.8	56.7	6.9	88	10.39	76.5	22.7	0.41	274	5.7	75	15	..
39	1	5.6	55.9	6.9	88	9.45	77.5	19.8	0.33	284	5.9	75	15	22–24
40	2	4.9	56.0	6.9	86	11.96	76.0	18.9	0.31	326	4.8	75	15	21
41	15	5.5	55.9	6.9	88	10.90	76.6	23.0	0.31	350	5.4	63	15	21
42	2	6.5	56.31	6.5	68	7.15	74.2	5.4	..	1324	5.3	240	15	23
43	2	5.8	57.0	6.7	68	8.01	74.0	5.7	0.23	485	5.3	240	15	..
44	1.5	6.1	58.3	6.7	68	7.26	74.0	5.1	..	567	6.5	240	15	..
45	1	6.1	55.1	6.9	89	9.02	77.4	20.0	..	682	6.0	63	15	..
46	1.5	5.5	56.0	6.7	82	11.98	76.4	19.5	..	336	....	63	0	21
47	1.5	5.7	55.5	6.8	82	12.59	76.0	19.6	0.25	350	4.8	63	0	22
48	1.5	5.7	55.3	6.8	82	10.51	76.7	20.4	0.27	300	4.8	63	0	22
49	2	5.9	56.7	6.8	83	12.90	76.7	18.1	..	428	5.3	68	15	21–24
50	2	5.9	58.0	6.8	83	12.14	77.2	17.2	..	394	5.9	68	15	24
51	1.5	6.0	57.9	6.8	83	12.00	77.3	17.0	..	296	5.9	68	15	21
52	2	5.8	57.1	6.8	84	11.60	76.7	17.8	..	356	5.6	63	15	24
53	2	5.8	57.5	6.8	84	10.75	76.6	15.9	..	538	6.1	63	0	21
54	2	6.1	57.9	6.8	84	10.26	75.8	18.6	..	318	5.9	63	0	22
55	2	5.9	58.2	6.8	84	10.48	76.6	19.6	..	314	5.3	63	0	22
56	2	6.1	58.0	6.9	84	9.78	77.0	18.1	..	376	6.0	63	0	25
57	2	6.2	58.0	6.9	84	13.83	76.5	19.3	..	358	5.1	63	0	24
58	2	6.0	56.6	6.9	84	13.18	77.2	19.4	..	302	4.7	63	0	24

The method followed in coagulating the sludge was changed from time to time as the work progressed. During the first part of the tests with the Genter filter, the coagulant was added one-third at a time with 4-minute intervals between additions and with a 5-minute stirring period before filtering. In the operation of the Oliver filter it was observed that a thicker and better cake was obtained during the first part of a run as compared with the latter part. It was believed that the reason for this condition was the long contact period of that portion of the coagulant and the sludge drawn off at the end of a run.

A test was, therefore, made to confirm this belief. A definite quantity of ferric chloride was thoroughly mixed with digested sludge, which was then divided into eight parts. After allowing the materials to stand for periods of time varying from 1 to 56½ minutes, the sludge was dewatered in a Büchner funnel. The times for the moisture to leave the surface of the cake and for the cake to crack away from the edge of the funnel were observed. As indicated in Figure 1, dewatering was much more rapid when the sludge was filtered shortly after the coagulant had been added.

As a result of these tests, the contact period of the coagulant with the sludge was decreased. During Tests 1 to 28, inclusive (Table I), with the Genter filter, one-third of the coagulant was added at a time with 3-minute intervals between additions and with a 3-minute period following the last application. During Tests 29 to 58 (Table I) one-half of the coagulant was added at a time with 2-minute intervals of stirring between additions and after the final application. Except for a few of the recorded tests, the sludge dewatered with the Oliver filter was coagulated by adding the conditioner during a one-minute interval, after which the sludge was stirred for two minutes before filtering.

Dewatering with a Bartlett Hayward Filter (Genter Type)

The experiments on the dewatering of sludge with a Bartlett Hayward filter were begun Sept. 3, 1931, and concluded July 26, 1932. The work as a whole falls into two parts. During the first part a series of preliminary investigations were made, which served as a guide for the second portion of the investigation.

Description of Filter.—The Genter filter, shown in Figure 2, consists of 20 vacuum tubes with a filter area of 16 sq. ft. The tubes are equally spaced around the periphery of a 30-in. diameter circle, and are secured at one end to a spider. Each tube is 3 in. in diameter, 18 in. long and connects with a filtrate pipe in the spider. The tubes and the spider set in a steel tank, into which the material to be dewatered flows. The dimensions of the tank are such that about 60 per cent of the tubes are above the top of it. The spider and the attached tubes are given a rotary motion by means of an electric motor.

Each tube consists of a central core or cylinder, made of metal or wood, on the outside of which is the filter medium, which can be woolen, cotton or metal cloth. Cores of various metals such as tinned iron, cast iron, copper-plated iron and iron tubes coated with an acid-proof paint were used. Wooden tubes were finally found to be the best, as they withstood the oxidizing action of ferric chloride. A longitudinal groove $^1/_4$ in. wide and varying in depth from $^1/_8$ to $^1/_2$ in. is provided along the outer edge of each tube for the passage of liquid or air. A stainless steel wire

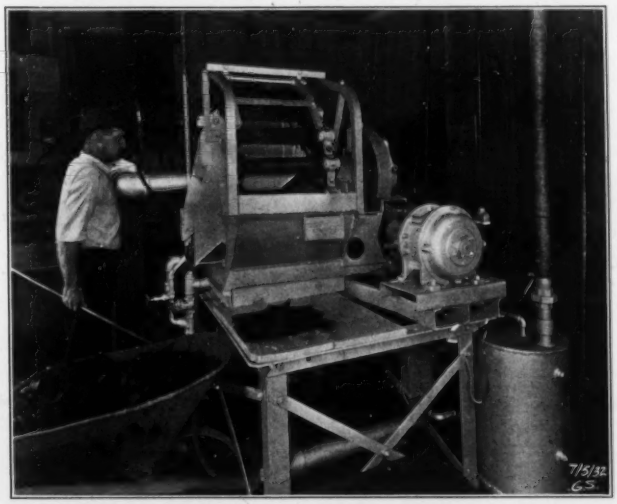


FIG. 2.—Genter Vacuum Filter, Baltimore Sewage Works.

0.049-in. in diameter is wound spirally around each tube with a space of $^3/_8$-in. between adjacent turns.

Only metal filter cloth was used during the test runs. Copper, phosphor bronze, Muntz metal, monel metal and pure nickel with 64 to 100 meshes per inch were tried. The difficulty with these metals was that in all probability they reduced a portion of the ferric chloride, and the resultant hydroxide eventually clogged the openings in the cloth. Filter material made of No. 00 brass plate with 625 holes per sq. in., each 0.02 in. in diameter, was tried. This material was not satisfactory, as the effluent often contained as much as 1000 p. p. m. of suspended solids.

Stainless steel cloth with 70 meshes per inch was finally used, and was found to be satisfactory. All of the results given in Tables I, II, III and IV were obtained when using stainless steel. Tests were also made using twilled stainless steel cloth with 74 by 80 meshes per inch. This material had to be discarded as it clogged. Some few experiments were made with hollow porous carbon tubes. These tests were of insufficient duration to determine whether this material would be satisfactory.

The filtering process consisted of applying a vacuum to the tubes. The liquid then flowed through the filter cloth and between the wire windings to the longitudinal groove in the core. From there it passed through the filtrate conduits in the spider to a rotary valve and then out of the machine. The rotary valve, which is mounted on one end of the drive shaft, controls the application of a vacuum to those tubes entering the wet sludge in the filter tank and the removal of the vacuum as the tubes leave the drying arc. The valve also permits the introduction of air at atmospheric pressure in order to loosen the cake just prior to its removal from the tubes. A vacuum is applied as the tubes rotate through an arc of about 220°, and air at atmospheric pressure is applied during the remainder of the cycle.

One of the distinct features of the filter is the way it rotates. The driving mechanism is at the valve end of the machine, and imparts an oscillatory movement to the spider and the attached tubes, which keeps the solids in the material to be filtered from settling. At the slow speeds the movement is first forward through an arc of about 14 degrees, then backward through an arc of about 10 degrees and again forward. When the speeds are faster, the forward movement is greater, amounting to about 33 degrees when the speed is 63 seconds per revolution. As the forward rotation is always somewhat greater than that in the opposite direction, the combined movement is a forward one. During the tests, the maximum number of oscillations was 30 per minute with a rotating speed of $2^1/_2$ minutes per revolution. Toward the end of the experiments when the speed of rotation was 63 seconds per revolution, it was not necessary to oscillate the tubes at all. The oscillating impulse is obtained by means of a small auxiliary motor attachment.

During the first part of the tests, the dried cake was removed by means of stiff rubber wipers. These were soon replaced, however, by a more effective cleaning device. This consisted of revolving bronze collars with ratchet teeth on the outer periphery. Each tube was provided with two collars, one at each end. The two collars were connected by means of two thin manganese bronze blades set diametrically opposite each other. The inner edges of the blades were about $^1/_{32}$ in. from the filter cloth. Each blade was slightly pitched in order to give a lifting action to the dried sludge. During the filtering period the blades became imbedded in the cake. At the point where the sludge was removed, each tube passed

under two metallic stationary arches provided with teeth. These teeth came in contact with the teeth on the above-mentioned bronze collars, causing the blades on each tube to revolve and lift the cake free of the tube. The material dropped into a steel chute. In a filter of commercial size this chute would be replaced by a belt conveyor. The auxiliary equipment consisted of a vacuum pump, a filtrate pump, compressor and other miscellaneous apparatus.

Dewatering Digested Sludge.—The work during the first seven months was of a preliminary character, and consisted of experimenting with different types of filter cloth, different coagulants, various methods of cake removal, together with numerous other tests. During this period a

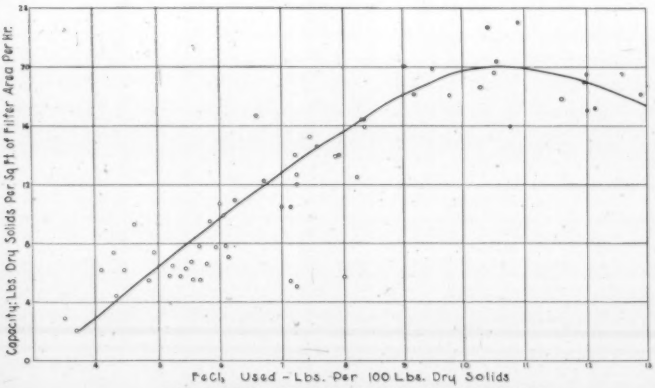


FIG. 3.

satisfactory means of removing the cake from the filter tubes was developed. It was furthermore learned that the capacity of the filter depended upon its speed. During the earlier part of the investigation the machine was operated at from 5 to 8 min. per revolution, while during the latter part of the work the speed was as fast as 63 sec. per revolution.

The preliminary work was followed by a group of 58 tests, each of which lasted from 1 to 14 hrs. The results of this latter work are given in Table I. The solids in the wet sludge dewatered varied from 4.8 to 6.5 per cent, the volatile solids from 55.1 to 61.1 per cent and the pH values from 6.5 to 7.0.

The quantity of anhydrous ferric chloride used varied from 3.54 to 13.83

lb. per 100 lb. of dry solids, with an output of from 2.1 to 23.0 lb. of dry cake per square foot of filter area per hour. The relationship between the capacity of the machine and the amount of coagulant is shown in Figure 3. According to this graph a cake containing 2.8 lb. of dry solids per square foot of filter area per hour may be expected when using 4 lb. of anhydrous ferric chloride per 100 lb. of dry solids. As the quantity of ferric chloride is increased, the output also increases with an average maximum of about 20 lb. of dry solids per square foot of filter area per hour. The maximum moisture in the cake was 80.5 per cent, the minimum was 74.0 per cent and the average 76.7 per cent. The effluent contained a maximum of 1324 p. p. m. of suspended solids, a minimum of 242 p. p. m. and an average of 512 p. p. m.

The speed of the filter was varied, depending upon the quantity of ferric chloride used. When applying a minimum of 3.54 lb. of anhydrous ferric chloride per 100 lb. of dry solids, the filter made one revolution in 5 minutes, and when using 13.83 lb. of coagulant, the speed was one revolution in 63 seconds. The use of larger quantities of coagulant made it possible to run the filter faster, and what was most important of all was to increase greatly the output. It might be supposed that the moisture of the cake would be greater when operating at the faster speeds, as the vacuum would be applied for a shorter period of time. An examination of the results indicate, however, that the moisture of the cake was comparatively independent of the speed.

During Tests 1 to 52, inclusive, the vacuum tubes were usually oscillated about 15 times a minute. For the remainder of the tests the oscillating movement was discontinued, and good results were obtained. During these latter tests the passage of the vacuum tubes through the wet sludge was sufficiently fast to keep the material in suspension. The vacuum was generally maintained above 20 inches of mercury.

Dewatering Semi-Digested Sludge.—Ten tests, each lasting from 1 to 1½ hrs., were made to see how well the filter would dewater semi-digested sludge. As indicated in Table II the material had an average of 5.9 per cent solids, 62.1 per cent volatile matter and an average pH value of 6.6. The anhydrous ferric chloride added averaged 5.18 lb. per 100 lb. of dry solids, and the corresponding cake production contained 2.8 lb. of dry solids per square foot of filter area per hour. The effluent was high in suspended solids with an average of 1002 p. p. m. It was necessary to operate the filter at the slow speed of 360 sec. per revolution.

These tests were of sufficient duration to indicate that it was practicable to dewater semi-digested sludge. The capacities, however, were very much less than when filtering digested material. There was no indication, however, that the filter tubes clogged. The effluent from the semi-digested sludge, with an average of 1002 p. p. m. of suspended solids,

TABLE II

SEMI-DIGESTED SLUDGE DEWATERED WITH A GENTER FILTER

(Coagulant: $FeCl_3$. Tests made May 31 to June 6, 1932)

Test No.	Duration of Test Hrs.	Sludge Added: Solid Content, %	Sludge Added: Volatile Matter, %	Sludge Added: pH	Sludge Added: Temperature, ° F.	Anhydrous $FeCl_3$ Used per 100 Lb. Dry Solids, Lb.	Cake: Moisture, %	Cake: Dry Cake per Sq. Ft. of Filter Area per Hr., Lb.	Cake: Thickness, In.	Effluent: Suspended Solids, P. p. m.	Effluent: pH	Filter Operation: Speed, Sec. per Rev.	Filter Operation: Oscillations per Min.	Filter Operation: Vacuum, In.
1	1.5	5.7	62.9	6.3	68	6.77	74.4	4.2	0.30	385	5.3	360	15	24
2	1.5	5.7	62.5	6.3	68	5.82	73.7	3.9	0.28	425	5.1	360	15	24
3	1.5	5.9	63.3	6.3	68	5.55	74.3	3.4	0.30	587	5.9	360	15	24
4	1	6.2	64.5	6.6	68	4.42	76.1	2.5	..	752	5.5	360	15	24
5	1.5	5.8	62.1	6.6	75	5.22	75.5	2.6	..	1274	5.9	360	15	22
6	1.5	5.9	61.2	6.7	75	4.65	75.5	2.7	..	972	5.1	360	15	23
7	1	5.6	62.4	6.7	75	4.44	75.7	2.1	..	1380	5.9	360	15	23
8	1.5	5.7	61.0	6.7	73	5.69	75.8	2.6	..	1520	6.5	300	15	19
9	1.5	5.7	59.4	6.7	73	5.23	75.7	1.9	..	1118	6.6	360	15	21
10	1.25	6.7	..	6.7	73	4.05	75.5	1.8	..	1604	6.7	360	15	22
Average	1.38	5.9	62.1	6.6	71.6	5.18	75.2	2.8	0.29	1002	5.9	354	15	23

TABLE III

RAW SLUDGE DEWATERED WITH A GENTER FILTER

(Coagulant: $FeCl_3$. Tests made June 3, 1932)

	Min.												
1	39	4.4	71.4	4.9	68	8.18	71.9	2.7	0.09	1782	3.4	180	15	14
2	15	4.0	72.1	4.9	68	8.24	73.1	1.3	..	1392	3.5	180	15	14
3	15	2.8	73.2	4.9	68	10.74	73.8	1.1	..	1174	...	240	15	14
4	14	3.0	73.0	4.9	68	12.07	74.9	1.3	..	1088	3.3	240	15	14
Average	21	3.6	72.4	4.9	68	9.81	73.4	1.6	0.09	1359	3.4	210	15	14

would be more unsuitable for disposal than the effluent from the digested sludge, with 512 p. p. m. of suspended solids. If semi-digested sludge were dewatered at Baltimore, it is believed that the effluent would have to be settled before finally discharging it into the river.

Dewatering Raw Sludge.—Two groups of tests were conducted to determine how well the filter would dewater raw sludge. Throughout the first group the sludge was coagulated with ferric chloride. Four tests were made, each of which varied in length from 14 to 39 minutes. It was necessary to clean the filter tubes at the end of each test. As indicated by Table III, the raw sludge contained an average of 72.4 per cent volatile matter, 3.6 per cent solids and a pH value of 4.9. The machine produced, on the average, a cake containing 1.6 lb. of dry solids per square foot of filter area per hour, with the use of 9.81 lb. of anhydrous ferric chloride per 100 lb. of dry solids. The effluent, with 1359 p. p. m. of suspended solids, contained even more material than that from semi-digested sludge. From the tests that were made it would seem impracticable to dewater Baltimore raw sludge when using ferric chloride as a coagulant. The use of a large quantity of this chemical produced only a small output. The chief disadvantage, however, was due to the clogging of the filter cloth, which made it impossible to operate continuously.

The second group of experiments consisted of treating the raw sludge with paper pulp, lime and copperas. The results, which are given in Table IV, indicate that large quantities of paper pulp and coagulants were required, and the quantity of dry sludge dewatered was never high, the maximum being 2.6 lb. per sq. ft. of filter area per hour. Tests 13, 14 and 15 were made by treating the sludge with lime or lime and paper pulp, after which the pH value of the sludge was reduced by a method, the details of which will be published at a later date. It is possible to filter raw sludge when the preliminary treatment consists of the use of paper pulp, lime and copperas, but these materials have to be used in such quantities that the process is much more expensive than when digested sludge is dewatered.

Effect of Heat on Filtration.—It was believed that the heating of either the sludge or the diluted ferric chloride might increase the capacity of the filter. Several groups of tests were, therefore, made with the Genter machine to verify this belief. In one group the diluted coagulant was heated and added to the sludge; in another group the sludge was heated, and then the conditioner was added; and in the final tests the sludge and coagulant were mixed, and then heated. In none of these tests did the heating prove beneficial.

Dewatering with an Oliver Filter

The Oliver filter was brought to the Baltimore sewage works in December, 1931. This machine is a test unit with an effective area of 18 sq. ft.

TABLE IV

RAW SLUDGE DEWATERED WITH A GENTER FILTER

(Coagulant: Lime, $FeSO_4$ and Paper Pulp. Tests made July 19 to 25, 1932)

Test No.	Duration of Test, Min.	Sludge Added: Solid Content, %	Sludge Added: Volatile Matter, %	pH	Treatment: Dry Paper Pulp Added per 100 Lb. Dry Solids, Lb.	Treatment: $Ca(OH)_2$ Used per 100 Lb. Dry Solids, Lb.	Treatment: $FeSO_4$ Used per 100 Lb. Dry Solids Lb.	Cake: Moisture, %	Cake: Dry Cake per Sq. Ft. of Filter Area per Hr., Lb.	Cake: Dry Sludge Solids per Sq. Ft. per Hr., Lb.	Filter Operation: Speed, Min. per Rev.	Filter Operation: Oscillations, per Min.	Filter Operation: Vacuum, In.
1	12	3.8	73.9	4.6	18.1	72.3	0.0	63.5	...	...	6	15	18
2	20	3.8	73.9	4.6	18.1	72.3	19.9	72.8	1.8	0.9	6	15	13
3	20	3.8	73.9	...	18.1	72.3	36.1	72.3	1.7	0.9	6	15	12
4	20	3.8	76.8	...	70.3	37.6	8.2	78.2	2.4	1.3	6	15	15
5	15	4.4	..	...	59.1	29.4	4.8	74.4	2.2	1.2	6	15	19
6	20	4.2	..	...	34.8	25.8	2.1	76.8	2.0	1.2	6	15	22
7	20	4.2	..	...	23.9	25.2	3.4	72.9	1.8	1.2	6	15	17
8	20	3.5	..	...	30.2	31.7	4.3	74.2	1.6	1.0	6	15	16
9	15	3.6	..	...	39.5	35.1	4.8	71.7	2.6	1.5	6	15	19
10	15	2.7	77.4	...	44.1	31.3	5.6	71.6	2.9	1.7	6	15	20
11	15	2.3	78.8	...	41.7	18.3	5.0	74.8	2.0	1.3	6	15	20
12	15	3.2	75.8	...	16.0	61.3	4.4	76.8	1.6	0.9	6	15	19
13	11	2.3	78.5	...	22.9	91.7	0.0	62.8	3.9	1.7	6	15	21
14	20	5.3	72.8	...	20.8	8.3	0.0	73.6	3.1	2.4	6	15	22
15	15	7.7	71.2	...	0.0	51.3	0.0	63.6	3.6	2.6	6	15	21

The filter consists of a wood drum, 3 ft. in diameter and 2 ft. long, partly submerged in a cast iron tank, into which the wet sludge to be dewatered flowed. The installation at the Baltimore sewage works is shown in Figure 4, and an elevation and end view of a filter of standard design are given in Figure 5. The filter drum is constructed of cast iron spiders, to which are bolted wooden staves. The periphery is divided equally into sections or compartments by wooden strips, which run the full length of the drum parallel to the axis. Each section is provided with wooden drainage strips, over which is a 5-mesh, woven wire screen. Woolen cloth, which serves as the filter medium, is wrapped around the outer face of the

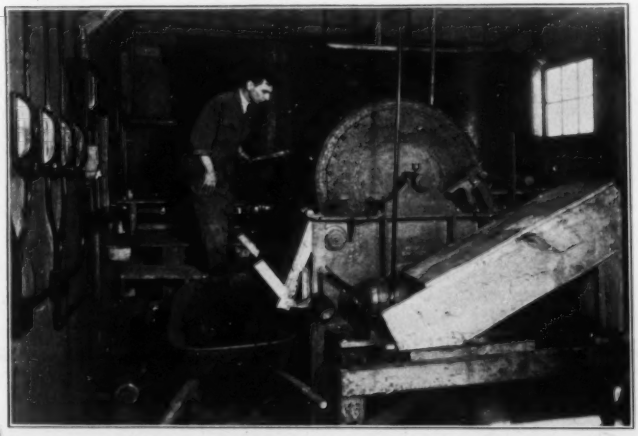


FIG. 4.—Oliver Vacuum Filter, Baltimore Sewage Works.

drum and is held in place by a No. 14 gauge steel wire, wound spirally around the cloth.

Each of the above-mentioned compartments is connected by a $^3/_4$ in. pipe to an automatic valve, mounted on the outer end of the trunnion of the machine. The drum revolves about a longitudinal shaft, which also acts as a support for the drum. The automatic valve controls the application of either a vacuum or compressed air to each of the compartments, depending upon their position in the cycle of operation. A vacuum pump and an air compressor with piping to the automatic valve were provided. The drum was rotated by means of a $^1/_2$-hp. motor, connected through a variable speed transmission and worm gear rèducer to the drum shaft.

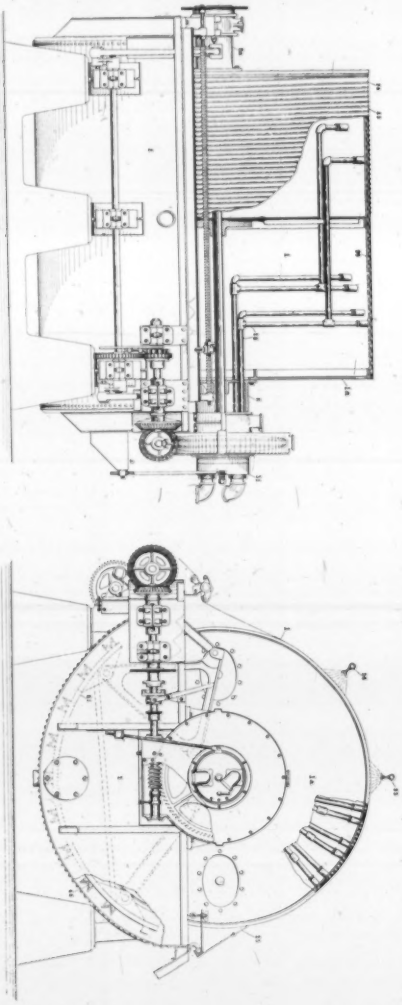


FIG. 5.—Sectional and End Views of Oliver Vacuum Filter.

The tank was partially filled with wet sludge, to which a definite quantity of ferric chloride had been added. The depth of submergence of the drum in the sludge was usually about 7 in. A swing type agitator was provided in the tank to keep the sludge thoroughly mixed. As the drum rotated and a portion of its surface emerged from the sludge, a layer of cake about $^1/_2$ in. thick adhered to the wool felt, due to the application of a vacuum on the compartment beneath the felt. This vacuum was maintained uninterruptedly as the drum continued to revolve. On the opposite or discharge side of the filter there was a steel scraper for removing the dried cake. Before each compartment of the drum reached this scraper, however, compressed air was applied to the compartment. Air was thus forced through the felt, and the cake was loosed prior to its removal. A spray pipe with jets was provided at one side of the drum so that the filter cloth could be cleaned whenever necessary.

The experiments using the Oliver filter were begun Jan. 26, 1932, and concluded Aug. 29, 1932. The work falls into two sections or parts. The first part of the investigation, which lasted from Jan. 26 to Feb. 17, 1932, was preliminary in character, and was conducted to learn how the capacity of the machine was affected by various quantities of ferric chloride by the drum speed and by the concentration of solids in the sludge. As all of these preliminary tests were of comparatively short duration, usually not over 15 min. long the results have not been given. For them have been substituted the data obtained during the second and more important part of the experiment. During this part of the investigation three kinds of sludge were dewatered: digested, semi-digested and raw material. Most of the work covered the filtration of digested sludge as this was considered the most important phase of the problem.

Dewatering Digested Sludge.—The filtering of digested sludge was done at two different times. The first group of tests was made from Feb. 18 to April 5, 1932, and the second from July 8 to Aug. 29, 1932. As somewhat different results were obtained during these two test periods, the findings will be discussed separately. From Feb. 18 to April 5, 1932, 27 tests were made (see Table V), each of which varied in length from a minimum of $1^1/_2$ to a maximum of 14 hrs.

The preliminary experiments had indicated that the factor most instrumental in controlling the output of the filter was the amount of ferric chloride used. The quantity of this coagulant was, therefore, varied from 3.79 to 8.11 lb. of anhydrous material per 100 lb. of dry solids to be filtered. As indicated by Curve 1, Figure 6, the quantity of sludge dewatered increased as a greater quantity of ferric chloride was used until an average maximum output of about 11.5 lb. of dry solids per square foot of filter area per hour were dewatered when using about 6.8 lb. of anhydrous ferric chloride per 100 lb. of dry solids. The capacity of the filter increased

TABLE V

DIGESTED SLUDGE DEWATERING WITH AN OLIVER VACUUM FILTER

(Coagulant: $FeCl_3$. Tests made February 18 to April 5, 1932)

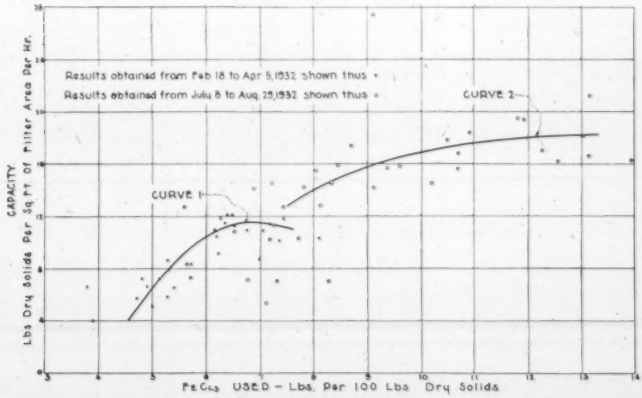
Test No.	Duration of Test, Hrs.	Sludge Added: Solid Content, %	Sludge Added: Volatile Matter, %	Sludge Added: pH	Sludge Added: Temperature, °F.	Anhydrous $FeCl_3$ Used per 100 Lb. Dry Solids, Lbs.	Cake: Moisture, %	Cake: Dry Cake per Sq. Ft. of Filter Area per Hr., Lb	Cake: Thickness, In.	Effluent: Suspended Solids, P. p. m.	Effluent: pH	Filter Operation: Speed, Sec. per Rev.	Filter Operation: Vacuum, In.
1	2	6.3	57.5	6.9	68	6.56	74.7	11.2	0.14–0.19	126	6.5	60	5–12
2	2	6.3	..	6.9	70	6.22	73.4	9.1	0.15–0.19	...	6.3	83	5–9
3	2	6.7	57.3	6.9	..	5.28	71.9	5.8	0.14–0.18	85	6.5	129	5–7
4	2	6.9	55.7	...	70	5.41	72.5	6.5	0.13–0.18	106	6.5	115	9
5	4	6.3	56.0	6.9	77	6.34	74.0	11.5	0.19–0.23	...	6.4	84	17–18
6	6.11	6.3	57.1	7.0	77	6.19	74.5	10.4	0.18–0.24	100	6.3	84	17–18
7	7	5.5	57.8	6.9	74	6.75	73.5	10.9	0.18–0.23	37	6.1	84	17–18
8	4	6.2	56.2	6.9	75	6.39	74.5	12.1	0.20–0.26	22	6.4	84	19
9	4	5.6	..	6.9	74	7.45	73.8	11.8	0.15–0.24	62	6.1	84	17–19
10	6	7.9	57.2	6.9	73	3.79	75.5	6.6	0.15–0.19	76	6.6	120	17–19
11	4	6.1	56.3	6.9	72	6.48	73.4	12.1	0.18–0.22	26	6.3	84	17–19
12	6.75	6.4	56.0	6.9	75	6.26	73.9	11.8	0.16–0.24	80	6.5	84	14–19
13	5.5	6.1	57.2	6.9	78	7.05	76.2	10.9	0.18–0.24	40	6.2	84	7–17
14	7	6.0	58.2	6.9	72	6.15	72.2	10.9	0.16–0.24	32	6.2	84	14–18
15	6.5	5.8	57.0	6.9	72	7.19	74.1	11.4	0.16–0.29	32	6.1	70–84	14–17
16	14	5.4	57.2	6.9	77	8.11	74.5	10.3	0.15–0.20	61	6.2	84	16–19
17	6	5.3	58.2	6.7	79*	7.37	75.8	10.1	0.15–0.20	93	6.5	84	15–19
18	7	5.7	58.7	6.7	75*	6.98	75.2	8.7	0.15–0.21	69	6.5	84–120	16–20
19	4	5.2	56.0	6.9	75*	4.71	75.8	5.7	0.18–0.25	66	6.7	157	18–21
20	3	5.5	57.4	6.8	75*	5.15	74.7	7.2	0.18–.021	42	6.3	120	17–20
21	3	5.4	57.2	6.9	75*	5.73	74.0	8.3	0.18	...	6.2	100	16–20
22	3	5.3	57.2	6.8	73*	4.91	76.6	6.6	0.19–0.20	50	6.4	120	18–20
23	2.8	5.3	57.5	6.9	73*	3.91	77.1	4.0	0.15–0.16	157	6.7	157–190	18–20
24	2	5.9	58.5	6.9	69	4.81	76.6	7.2	0.20	67	6.5	120	18–21
25	1.5	5.9	57.2	6.7	66	5.29	76.5	8.6	0.20	82	6.3	100	18–20
26	2	6.4	58.3	6.8	66	5.32	78.3	7.9	0.20–0.21	115	6.5	90	17–20
27	2	5.6	59.9	6.7	66	5.01	77.6	5.1	0.16–0.19	108	6.5	120	17–19

* Estimated.

with its speed, but high speeds could be used only with large amounts of ferric chloride.

During the experiments the average moisture in the cake was 74.8 per cent, with a minimum of 71.9 per cent and a maximum of 78.3 per cent. At these moistures the sludge could easily be handled with a spade. The cake was sufficiently dry to hang together in a continuous sheet with a thickness varying from $^1/_8$ to $^1/_4$ in. The effluent from the filter was clear, and in appearance would compare favorably with that from a well operated activated-sludge plant. The suspended solids averaged 72 p. p. m., and the pH value varied from 6.1 to 6.7.

The second group of experiments on the dewatering of digested sludge


Results obtained from Feb 18 to Apr 5,1932 shown thus +
Results obtained from July 8 to Aug 29,1932 shown thus +
CURVE 1
CURVE 2
CAPACITY
Lbs Dry Solids Per Sq Ft Of Filter Area Per Hr.
FeCl3 USED - Lbs. Per 100 Lbs Dry Solids

CAPACITY OF OLIVER FILTER WHEN DEWATERING DIGESTED SLUDGE COAGULATED WITH $FeCl_3$

FIG. 6.

was begun July 8 and concluded Aug. 29, 1932. As indicated in Table VI, 39 tests were made, each of which varied from a minimum of 56 minutes to a maximum of 2 hrs. The chief purpose of the latter group of experiments was to see if a greater output of sludge cake could be obtained than during the earlier work, by using larger amounts of ferric chloride and operating the filter at a faster speed.

During the investigation the volatile matter in the sludge varied from a minimum of 51.5 to a maximum of 58.3 per cent with an average of 54.8 per cent. The solid content averaged 7.43 per cent, and the pH value fluctuated between 6.7 and 6.9. The sludge appeared to be better digested than that dewatered earlier in the year, and the solid content was higher,

It would seem that both of these conditions would cause the material to filter more easily.

The quantity of ferric chloride used was varied from 5.60 to 17.11 lb. per 100 lb. of dry solids in the sludge, with an output of from 5.3 to 27.4 lb. of dry cake per square foot of filter area per hour. It should be noted that only 6 tests were made when using less than 7.0 lb. of ferric chloride per 100 lb. of dry sludge solids. Many attempts were made to dewater the sludge when using less than this amount of coagulant, but the sludge filtered poorly, with the production of a wet cake. It was possible, however, to use somewhat smaller quantities of ferric chloride during the latter part of the tests than during the first part of the work.

No reason can be given for the inability of the filter to dewater the sludge when using from 4 to 6 lb. of ferric chloride per 100 lb. of dry solids, as was done during the tests conducted from February to April, 1932. A group of laboratory tests was made using a Büchner funnel to see how well the sludge would filter when coagulated with various quantities of ferric chloride. No better success was had with these small-scale tests than with the filter in the field. Furthermore, a few tests were made using the Genter filter, with the same unsuccessful results. The sludge was dried in the laboratory on an improvised sand bed, but it did not filter as well as digested material obtained from other digestion tanks at the sewage works. The only reason that might be given for the poorer filtrability of the sludge, as compared with the material dewatered from February to April, 1932, is that the former solids were collected in summer whereas the latter was obtained in winter. It is possible that sludge collected in summer has characteristics which make it more difficult to filter than winter sludge. Regarding the tests conducted during July and August, 1932, it should be noted that the sludge could be filtered more easily when using smaller quantities of ferric chloride toward the end of the tests. In order to determine the filtrability of the digested sludge under all conditions a continuous series of tests lasting at least one year should be made.

The results of these latter tests, in which the capacity of the filter was determined when using different amounts of ferric chloride, are shown by Curve 2 in Figure 6. Very frequently it was impossible to get satisfactory results with less than about 7.5 lb. of ferric chloride per 100 lb. of dry solids. The curve, therefore, has not been projected below this amount. For the type of sludge handled it has been estimated that 8.0 lb. of ferric chloride would be needed per 100 lb. of dry solids with production of 14 lb. of dry solids per square foot of filter area per hour. A maximum output of approximately 18 lb. of dry solids was obtained when using about 12 lb. of ferric chloride per 100 lb. of dry solids.

The moisture of the cake varied from 72.6 to 78.2 per cent with an average of 75.0 per cent, and the thickness of the cake was about 0.22 in. The

TABLE VI

DIGESTED SLUDGE DEWATERED WITH AN OLIVER FILTER

(Coagulant: $FeCl_3$. Tests made July 8 to August 29, 1932)

Test No.	Duration of Test, Hr.	Sludge Added				Anhydrous $FeCl_3$ Used per 100 Lb. Dry Solids, Lb.	Cake			Effluent		Filter Operation	
		Solid Content, %	Volatile Matter, %	pH	Temperature, ° F.		Moisture, %	Dry Cake per Sq. Ft. of Filter Area per Hr., Lb.	Thickness, In.	Suspended Solids, P. p. m.	pH	Speed, Sec. per Rev.	Vacuum, In.
1	2	6.0	58.0	6.9	87	9.12	75.9	14.2	0.18	101	6.1	56	17
2	2	6.2	58.3	6.9	87	10.69	75.1	15.6	0.19	40	6.0	50–56	17
3	1	6.3	57.5	6.9	87	6.77	76.9	7.1	..	261	6.7	84–104	17
4	1	7.3	54.5	6.8	84	9.62	75.1	15.8	0.25	502	6.0	70	17–18
5	56 min.	7.5	53.7	6.8	84	8.34	76.0	14.6	0.23	676	6.3	70	17
6	1	7.6	55.1	6.8	84	7.18	76.7	10.2	..	616	6.5	84	18
7	1	7.7	56.0	6.7	82	8.34	75.8	14.5	0.23	84	6.3	70	13–18
8	1	7.5	55.6	6.7	82	7.27	76.2	11.3	..	146	6.5	70	17
9	1	7.8	54.9	6.7	84	8.45	76.2	15.9	0.23	110	6.3	70	18
10	1	7.6	54.1	6.7	84	9.38	75.5	15.7	0.22	109	6.3	70	18
11	1	7.8	55.2	6.7	84	10.93	75.5	18.4	0.23	...	5.4	56	17
12	1	7.7	54.2	6.7	85	10.49	75.4	17.8	0.23	...	5.7	56	..
13	1	8.0	55.0	6.7	85	8.14	75.6	12.8	0.23	67	6.3	84	17–18
14	1	8.7	54.3	6.7	84	8.69	75.1	17.4	0.25	47	6.3	70	..
15	1	8.1	53.9	6.7	84	7.83	75.9	14.2	0.21	61	6.3	70	..
16	1	7.9	53.7	6.7	84	7.32	75.6	7.0	..	...	6.5	120	..

17	1	9.9	53.4	6.7	82	7.21	74.9	14.5	..	154	6.3	84	17–18
18	1	9.0	53.5	6.7	84	9.11	76.2	27.4	..	38	5.4	50–44	17–18
19	1.75	9.1	..	6.7	86	5.60	72.6	12.7	..	118	10.6+	70–106	17–19
20	2	6.9	54.5	6.8	82	10.18	75.1	14.5	0.22	85	6.0	64	17–18
21	2	7.2	54.5	6.8	..	7.72	75.8	10.3	0.20	136	6.4	104–80	17
22	1	6.7	55.3	6.8	82	7.12	74.0	5.3	0.16	185	6.6	120–157	16–17
23	2	6.7	51.5	6.8	86	17.11	73.6	15.9	0.25	62	4.8–	70–84	18
24	2	6.9	55.7	6.8+	86	13.13	73.7	16.6	0.23	31	4.8–	70	17
25	2	6.9	54.9	6.8+	86	13.04	74.1	18.1	0.22	30	4.8–5.3	70	17–19
26	2	6.6	55.0	6.8+	86	12.27	73.8	17.0	0.23	34	4.8–5.5	70	17
27	2	6.6	54.4	6.8+	86	10.71	74.0	16.8	0.22	32	5.3–5.8	70	17–18
28	2	7.4	53.9	6.8+	85	11.80	74.1	19.5	0.25	32	5.0–5.3	70	18
29	2	7.8	53.6	6.8	86	11.92	74.5	19.4	0.26	24	4.8–5.2	70	18
30	1.58	8.0	54.4	6.8	86	13.15	74.4	21.2	0.26	23	4.8–	70–56	18
31	2	6.5	55.2	6.9	85	13.94	73.6	16.3	0.23	9	4.8–	70	17
32	1.75	6.7	55.3	6.9	85	12.58	74.0	16.2	0.24	7	4.8–	70	17–18
33	2	7.0	56.4	6.8	86	8.05	74.2	15.5	0.26	85	6.0	84	18
34	2	6.9	56.2	6.8	86	6.52	75.1	10.8	0.20	156	6.5	84	16–19
35	1.75	7.0	55.5	6.8	86	5.71	74.9	7.3	0.25	223	6.6	120	18
36	2	7.3	53.9	6.8	86	7.44	73.6	12.7	0.20	121	6.3	84	17–18
37	2	5.7	54.9	6.8	86	8.28	74.7	7.0	0.17	226	6.5	120	18
38	1.92	8.6	53.0	6.8	88	6.87	74.0	14.1	0.20	..	6.4	84	15–17
39	2	8.6	53.0	6.8	88	5.65	74.0	8.3	0.20	...	6.7	120	15–17

suspended solids in the effluent averaged 136 p. p. m. As a general rule the quantity of solids in the effluent varied inversely with the amount of ferric chloride used. When large quantities of cake were produced, the speed of the drum was as fast as 50 sec. per revolution.

Dewatering Semi-Digested Sludge.—Six tests, covering a total period of $11\frac{1}{2}$ hrs., were conducted to see how well the filter would dewater semi-digested sludge. The results are given in Table VII. The wet material contained an average of 63.0 per cent volatile matter, 6.7 per cent dry solids and had a pH value of 6.8 to 6.9. The capacity of the machine was considerably less than when dewatering digested sludge. However, the material filtered satisfactorily. The machine produced a cake containing an average of 3.4 lb. of dry solids per square foot of filter area per hour when using 5.0 lb. of anhydrous ferric chloride per 100 lb. of dry solids. The average moisture in the cake was 73.9 per cent. Although the effluent contained more colloidal solids than when dewatering digested sludge, the suspended solids averaged only 44 p. p. m. The tests indicated that it was perfectly feasible to filter semi-digested sludge obtained at Baltimore.

Dewatering Raw Sludge.—In addition to dewatering digested and semi-digested sludge, a few tests were made to see if raw sludge could be filtered. Four runs (see Table VIII) were made, each of which lasted from 18 to 40 minutes. The exact age of the sludge dewatered was not known, but judging by the volatile content, which averaged 76.4 per cent, the odor and the physical characteristics, the material was undigested. When using an average of 5.23 lb. of ferric chloride per 100 lb. of dry solids, a cake containing 4.5 lb. of dry solids per square foot of filter area per hour was obtained, with an average moisture content of 75.9 per cent. The effluent was highly colloidal, and contained 69 p. p. m. of suspended solids. The tests were all of short duration due to clogging of the filter cloth.

Coagulation with Chlorinated Copperas.—As copperas can be obtained in large quantities in Baltimore from a local manufacturing plant at a low price, it was considered advisable to make a sufficient number of tests using chlorinated copperas as a coagulant in order to determine the capacity of the filter. As indicated in Table IX a group of 16 runs was made. The quantity of anhydrous chlorinated copperas used was varied from 9.41 to 17.19 lb. per 100 lb. of dry solids. The capacity of the filter when using various quantities of coagulant is shown graphically in Figure 7. A maximum capacity of about 11.0 lb. of dry solids per square foot of filter area per hour can be expected. The cake contained an average of 74.7 per cent moisture, and had an average thickness of 0.20 in. The effluent was comparatively clear, with an average of 103 p. p. m. of suspended solids. Good results could be expected when using 10 lb. of chlorinated

TABLE VII

SEMI-DIGESTED SLUDGE DEWATERED WITH AN OLIVER FILTER

(Coagulant: $FeCl_3$. Tests made April 6 to 8, 1932)

Test No.	Duration of Test, Hr.	Sludge Added: Solid Content, %	Sludge Added: Volatile Matter %	Sludge Added: pH	Sludge Added: Temperature, ° F.	Anhydrous $FeCl_3$ Used per 100 Lb. Dry Solids, Lb.	Cake: Moisture, %	Cake: Dry Cake per Sq. Ft. of Filter Area per Hr., Lb.	Cake: Thickness, In.	Effluent: Suspended Solids, P. p. m.	Effluent: pH	Filter Operation: Speed, Sec. per Rev.	Filter Operation: Vacuum, In.
1	1.50	6.0	64.2	6.8	59	4.50	73.6	3.0	0.18–0.20	31	6.2	285	20–22
2	1.00	5.7	61.8	6.8	51	5.26	75.2	2.1	0.19–0.20	111	6.5	285–380	19–21
3	3.50	6.6	63.7	6.8	62	5.48	72.6	3.6	0.23–0.25	24	6.0	285	19–22
4	2.00	7.9	62.5	6.8	52	5.46	72.8	4.6	0.23–0.25	41	5.5	240–208	16–21
5	2.00	6.9	62.9	6.9	53	5.14	75.5	3.9	0.20–0.21	17	5.7	208	19–21
6	1.50	7.2	62.9	6.8	54	4.15	73.4	2.9	0.19	40	6.5	285	18–21
Average	1.92	6.7	63.0	6.8	55	5.00	73.9	3.4	0.21	44	6.1	270	19.9

TABLE VIII

RAW SLUDGE DEWATERED WITH AN OLIVER FILTER

(Coagulant: $FeCl_3$. Tests made March 24 to 29, 1932)

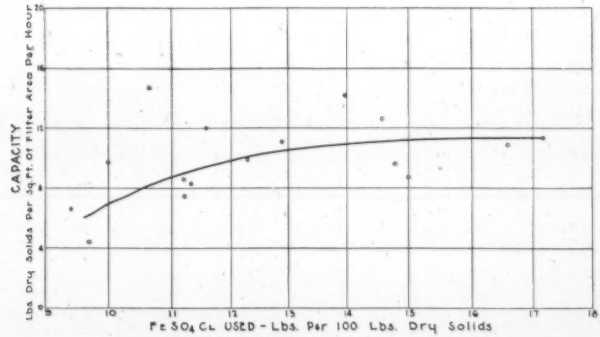
1	0.67	6.0	74.9	5.5	74*	6.04	74.5	5.3	0.13	43	...	157–120	19–21
2	0.30	7.3	76.6	4.9	78*	4.38	82.6	3.5	0.18–0.21	65	4.8–	157	18–20
3	0.37	7.4	76.8	4.9	78*	4.84	73.9	3.9	0.15–0.19	86	4.8–	157	18–20
4	0.50	6.4	77.2	4.9	79*	5.67	72.7	5.2	0.18–0.20	81	4.8–	157	20
Average	0.46	6.8	76.4	5.1	77*	5.23	75.9	4.5	0.17	69	4.8–	152	19.5

* Approximate.

copperas per 100 lb. of dry solids, when the output would be about 7 lb. of dry solids per square foot of filter area per hour.

Coagulation with Ferric Chloride and Lime.—A group of eight tests, each lasting from 28 to 60 minutes, was made to see to what extent the amount of ferric chloride could be reduced if lime was also used as a coagulant, when filtering digested sludge. The results of these tests are given in Table X. When using about $5^3/_4$ lb. of ferric chloride and 14 lb. of lime per 100 lb. of dry solids, a production of about 13 or 14 lb. of dry sludge solids per square foot of filter area per hour was obtained.

Adequate diffusion apparatus for proper chlorination of the copperas had not been secured at the time the Genter filter was available for similar



CAPACITY OF OLIVER FILTER WHEN DEWATERING. DIGESTED SLUDGE COAGULATED WITH $FeSO_4Cl$

FIG. 7.

experiments with this type of coagulant, but there seems no reason to suppose that it would have been any less effective when using this filter.

Cost of Sludge Filtration

One of the most important questions relating to sludge filtration pertains to the cost of the process. Three cost estimates of filtering all of the sludge at Baltimore have, therefore, been prepared. The first estimate is based on the results obtained previous to July 8, 1932, when using ferric chloride. The second and the third estimates are based on the experiments made with the Oliver filter during July and August, 1932, one when treating the sludge with ferric chloride and the other with chlorinated copperas. All of the estimates are based on dewatering $36^1/_2$ tons of dry solids daily for

TABLE IX

DIGESTED SLUDGE DEWATERED WITH AN OLIVER FILTER

(Coagulant: $FeSO_4Cl$. Tests made July 11 to August 29, 1932)

Test No.	Duration of Test, Hr.	Sludge Added: Solid Content, %	Sludge Added: Volatile Matter, %	Sludge Added: pH	Sludge Added: Temperature, ° F.	Anhydrous $FeSO_4Cl$ Used per 100 Lb. Dry Solids, Lbs.	Cake: Moisture, %	Cake: Dry Cake per Sq. Ft. of Filter Area per Hr., Lbs.	Cake: Thickness, In.	Effluent: Suspended Solids, P. p. m.	Effluent: pH	Filter Operation: Speed, Sec. per Rev.	Filter Operation: Vacuum, In.
1	1	7.0	56.2	6.9	88	11.19	74.0	8.6	0.25	114	6.1	120	17
2	1	6.9	56.9	6.9	88	9.41	76.5	6.6	0.16	210	6.3	120	17
3	3/4	6.6	58.8	6.9	88	12.30	75.1	9.9	..	37	6.1	84	15–18
4	1/2	8.0	55.8	6.7		11.20	75.8	7.5	..	98	...	84–120	17–18
5	1	7.0	..	6.6	82	15.01	75.7	8.7	..	129	6.1	84–106	17–18
6	1	7.4	..	6.6	82	11.32	76.9	8.3	..	207	6.3	106–120	17–18
7	1/2	7.2	..	6.6	82	9.67	76.8	4.4	..	314	6.5	127–157	17–18
8	1	7.3	..	6.7	78	14.80	76.3	9.6	..	38	5.8	84	17–18
9	1	7.3	55.4	6.8+	84	11.58	73.9	12.0	0.19	90	5.5	84	20
10	1	6.3	55.3	6.8+	84	17.19	74.3	11.4	0.20	47	5.3	84	19
11	1	6.3	56.1	6.8+	85	12.89	73.9	11.1	0.19	33	5.3	84	18
12	1	5.3	56.1	6.8	85	16.59	74.7	10.9	0.17	39	5.5	84	18
13	1	7.0	54.6	6.9	85	13.96	74.0	14.2	0.19	135	4.8	70	18
14	1	6.1	54.8	6.9	85	14.58	74.5	12.6	0.19	59	4.8–	70	18
15	1	7.5	54.4	6.8	86	9.99	70.4	9.7	0.19	55	5.9	120	18
16	1	9.0	52.4	6.7	84	10.64	73.1	14.7	0.24	43	5.1	84	16–19

TABLE X

DIGESTED SLUDGE DEWATERED WITH AN OLIVER FILTER

(Coagulant: Hydrated Lime and $FeCl_3$. Tests made July 21 to August 3, 1932)

Test No.	Duration of Test Min.	Sludge Added			Coagulant		Cake			Effluent		Filter Operation	
		Solid Content, %	Volatile Matter, %	pH	Temperature, °F.	Lime per 100 Lbs. Dry Solids, Lb.	Anhydrous $FeCl_3$ Used per 100 Lbs. Dry Solids, Lb.	Moisture, %	Dry Cake per Sq. Ft. of Filter Area per Hour, Lb.	Thickness, In.	Suspended Solids, P. p. m.	pH	Speed, Rev. per Rev.	Vacuum, In.
1	60	6.9	55.1	...	..	15.2	5.75	73.8	12.2	..	143	9.8	84	18–19
2	45	6.8	56.1	...	..	13.9	5.56	72.6	17.3	..	227	11.0+	70	17
3	60	7.2	54.6	...	82	15.0	5.41	73.4	16.6	..	272	9.9+	70	17
4	28	7.0	56.1	...	88	11.5	5.12	74.1	13.4	..	247	10.6+	84–120	17–18
5	60	6.5	52.5	6.7	82	13.94	5.57	73.6	11.9	0.19	82	..	84	17–18
6	60	6.7	53.9	6.7	82	14.76	6.91	72.7	13.7	0.20	65	..	84	17–18
7	40	7.0	55.4	...	..	10.78	4.32	73.3	5.2	..	15	..	120–190	18–19
8	60	6.9	56.3	...	83	14.51	5.75	74.3	10.6	..	...	..	84–100	17–18

300 days in the year and operating $7\frac{3}{4}$ hrs. daily. These estimates, covering the installation and the operating costs are given in Table XI.

With reference to Estimate 1, it has been assumed that $5\frac{1}{4}$ lb. of ferric chloride would be used per 100 lb. of dry solids dewatered (see Figure 3 and Figure 6, Curve 1). With this quantity of coagulant, the capacity of either of the filters was about 7.6 lb. of dry solids per square foot of filter area per hour. This output, together with the output assumed in preparing the other two estimates, has been reduced by 10 per cent to allow for a factor of safety. At this production 1380 sq. ft. of filter area would be needed to dewater $36\frac{1}{2}$ tons of dry solids daily. Four filters with a total area of 1400 sq. ft. have been provided. In preparing both Estimates 1 and 2 the cost of ferric chloride has been assumed to be $2\frac{1}{4}$¢ per lb.

Estimate 2 is based on the assumption that 8.0 lb. of ferric chloride would be used per 100 lb. of dry solids filtered, with an output of 14.0 lb. of dry solids per square foot of filter area per hour. A total area of 750 sq. ft. of filter cloth would be required, and two filters each with an area of 430 sq. ft. have been provided.

In preparing Estimate 3 chlorinated copperas has been considered to be the coagulant. When using 11.0 lb. of this chemical per 100 lb. of dry solids, the cake production is 8.8 lb. of dry solids per square foot of filter area per hour. It is assumed that four 350

sq. ft. filters would be required when using the above-mentioned quantity of coagulant.

Copperas can be purchased from a local manufacturer in Baltimore for $9.90 per ton. The estimated cost of 1000 lb. of anhydrous chlorinated copperas if made at the sewage works is

1485 lb. of $FeSO_4.7H_2O$ at $0.00495	$7.35	
Hauling	0.79	
190 lb. of Cl_2 at 2¼¢	4.28	$12.42

In addition to the filters included in the above-mentioned estimates there are also provided in each case two vacuum pumps, two compressors, two coagulating-dosing machines, two filtrate pumps, one sludge pump, two coagulant storage tanks, belt conveyors, pipes, valves, etc. This equipment would be erected in an attractive building of permanent construction.

Of the three estimates No. 1 is the lowest, the estimated cost of filtration being $4.22 per ton of dry solids. The estimated costs of dewatering sludge similar to that filtered during July and August of 1932 were $5.00 per ton of dry solids, when using ferric chloride, and $4.66 when coagulating with chlorinated copperas.

An additional estimate has been prepared, assuming coagulation of the sludge with ferric chloride and lime before filtration. The total cost when using these chemicals is estimated to be about $5.50. As this cost is considerably higher than when using ferric chloride alone or chlorinated copperas, the details of the estimate have not been given.

Cost of Air-Drying Sludge.—It is difficult to calculate exactly the cost of air-drying sludge at Baltimore on the dry solids basis. One reason is that it is hard to determine the total weight of dry solids handled due to inaccuracies in measuring the quantity of sludge removed from the sludge beds and in determining the solid content of the material. From the information available, however, it is estimated that the fixed costs of sludge beds for the 7-year period from 1925 to 1931, inclusive, have averaged $2.96, and the operating costs have been $3.27 or a total of $6.23 per ton of dry solids. This cost is greater than in many other places because the sludge takes longer to dry, due to insufficient digestion, and also because it is removed from the beds with a high moisture content. From these costs it is apparent that it is much cheaper to dewater the sludge at Baltimore by filtration than by air-drying.

Conclusions

The tests with both filters were sufficiently long and were carried out in enough detail to indicate that either one would perform the work for which it is designed. The merits of the process, therefore, are sufficiently

attractive to warrant the purchasing of filtering equipment for Baltimore as soon as funds are available.

The dewatering of digested sludge by vacuum filtration has a great many advantages over air-drying methods. In the first place the process can be confined to a small space whereas, when sludge is air-dried, considerable areas of land are frequently required. The question of the area needed is often of vital importance, especially where land is valuable or difficult to acquire. Furthermore, sludge beds—especially uncovered ones—generally present an unsightly and untidy appearance. On the other hand, the filtration of sludge can be confined in a building, and the material need not be visible until the cake is discharged from the filter.

Another advantage of using vacuum filtration is that less labor is required. One man can attend to the filters, which would serve a population of several hundred thousand persons, whereas to remove the sludge from drying beds one or more gangs of laborers would be needed.

Any change in the design of sewage works that will make them less conspicuous is to be desired. The construction of such plants underground as at Spring Lake, N. J., the housing of trickling filters and the provision of sludge beds with glass enclosures have meant that sewage works can be built in closer proximity to residential districts. This removal of treatment plants from the general view of the public has had the psychological effect of reducing the number of complaints. Where sludge filtration is practised, this benefit will be further augmented.

Due to insufficient digestion capacity or for some other reason, partially digested sludge is often run on drying beds. Unpleasant odors result, and persons living in the neighborhood raise valid objections. If the sludge is filtered inside a building, this difficulty is largely overcome.

One of the most cogent reasons for preferring sludge filtration is that it is entirely independent of weather conditions. Sludge drying on open beds is considerably retarded during rainy and winter weather. In the northern section of the United States and in localities having similar climates, the air-drying of sludge is inoperative during three or four months of the year. With sludge filtration, however, dewatering can be a continuous process, operating 24 hours a day, every day in the year.

This advantage has coupled with it another of considerable importance. With the general adoption of heated sludge tanks the production of digested sludge is uninterrupted. On the other hand the air-drying of sludge is not continuous. The result is that the rapid digestion of sludge in winter, when it cannot be air-dried, loses some of its advantages. Additional tank capacity must be provided to store this material until warmer weather permits its being dried. Where sludge is filtered, however, this additional capacity becomes unnecessary, and the treatment of the sludge goes on uninterruptedly.

The chief advantage, however, that sludge filtration affords, as compared with air-drying methods, is that, in so far as Baltimore conditions are concerned, the process is considerably cheaper. Where the sludge is digested in heated tanks, from which the gas is collected, and the material is then filtered, it is always possible to convert the energy in the gas into electric power, which can be used to operate the filters and the auxiliary equipment. Following such a plan should still further reduce the cost of sludge drying, especially where electric power is expensive.

With regard to the performance of the two filters, the moisture in the sludge from both machines was such that the cake could be handled on belt conveyors, in wheelbarrows or by other similar means. When ferric chloride was used as a coagulant, the average moisture in the digested sludge cake from the Genter filter was 76.7 per cent and that in the cake from the Oliver filter was about 74.9 per cent.

When dewatering semi-digested sludge the average water content of the cake from the former filter was 75.2 per cent and that from the latter was 73.9 per cent. The raw sludge cake from the Genter filter contained 73.4 per cent of moisture and that from the Oliver filter 75.9 per cent. These moistures are on the whole higher than the water content in sludge removed from drying beds. This difference, however, is not so marked at Baltimore, where the average moisture in the dried sludge during the past 7 years has been 72.1 per cent.

The effluent from the Oliver filter was better than that from the sludge drying beds. When dewatering digested sludge, the average suspended solids content of the effluent was 72 p. p. m. during the first group of tests made from February to April, 1932, and 136 p. p. m. during the tests made in July and August of 1932. The average suspended solids in ten samples of effluent from the sludge beds at Baltimore, when drying semi-digested material, was 210 p. p. m. and the 1-day B. O. D. (37½° C. incubation) was 109 p. p. m. The Genter filter produced an effluent with considerably higher suspended solids. These averaged 512 p. p. m. when dewatering digested sludge and 1002 p. p. m. when drying semi-digested material. The reason for the higher solids content in the Genter filtrate can be ascribed to the type of filtration medium employed. Seventy mesh stainless steel was used to demonstrate the practicability of this type of permanent medium. It is believed, however, that an effluent with fewer solids would be obtained when using a filter cloth with a finer mesh.

For Baltimore conditions with a flow of 60 M. G. D., contributed by approximately 790,000 people, it is estimated that the filtrate will amount to about 200 gal. per min. when dewatering sludge 7¾ hrs. daily for 300 days a year. This filtrate from the digested sludge could be added to the effluent flowing from the sewage works without producing any detrimental effects.

The curves shown in Figures 3 and 6 indicate that the capacities of the two machines were much the same when less than $6^1/_2$ lb. of ferric chloride were used per 100 lb. of dry solids. With the use of greater quantities of coagulant, however, the Genter filter gave slightly higher capacities than the Oliver machine. The former had an output of about 20 lb. of dry solids per square foot of filter area per hour when using about $10^1/_2$ lb. of anhydrous ferric chloride per 100 lb. of dry solids. The Oliver filter had a maximum production of about 18 lb. of dry solids per square foot of filter area per hour when using about 12 lb. of anhydrous ferric chloride per 100 lb. of dry solids. In considering the difference in capacity of these two filters, especially when large quantities of ferric chloride were used, it should be emphasized that the results are not based on dewatering the same sludge. The material dewatered by the Oliver machine was considerably harder to filter. It is believed that the capacities of these filters are about the same when ferric chloride is used as a coagulant.

TABLE XI

COMPARATIVE ESTIMATES OF SLUDGE FILTER INSTALLATIONS

	Estimate No. 1 4—350-Sq. Ft. Filters Using $5^1/_4$ Lb. of $FeCl_3$ per 100 Lb. of Dry Solids (1)	Estimate No. 2 2—430-Sq. Ft. Filters Using 8.0 Lb. of $FeCl_3$ per 100 Lb. of Dry Solids (2)	Estimate No. 3 4—350-Sq. Ft. Filters Using 11.0 Lb. of $FeSO_4Cl$ per 100 Lb. of Dry Solids (3)
Installation Costs			
Building	$32,000	$21,300	$32,000
Filtering equipment	54,000	37,300	54,000
Piping and valves	4,100	3,500	4,100
High tension power equipment	3,900	3,900	3,900
Out-door conveyors	1,000	1,000	1,000
Coagulant storage tanks	6,000	6,000	6,000
Chlorinating equipment	.....	.....	5,000
Total	$101,000	$73,000	$106,000
Operating Costs per Year			
Interest and depreciation	$9,596	$6,900	$10,231
Labor	1,500	1,500	1,500
Coagulant	25,870	39,420	29,920
Electric current at 1.9¢ per kw. hr.	7,085	5,238	7,085
Coal, oil, etc.	2,149	1,742	2,264
Total	$46,200	$54,800	$51,000
Cost per ton of dry solids	$4.22	$5.00	$4.66

If the results obtained with Baltimore sludge can be duplicated in other places, it would seem fair to assume that vacuum filtration offers an excellent means of drying digested sludge. The process is an economical and practicable method of sludge dewatering.

Acknowledgment.—The sewage works is under the general control of B. L. Crozier, chief engineer, Department of Public Works, and George E. Finck, sewerage engineer, with G. K. Armeling, superintendent. Acknowledgments are due to the Bartlett-Hayward Co., and Oliver United Filters, Inc., who furnished the filters, together with the personnel in these two organizations. Credit is due to P. L. Smith, Henry Weiner, J. W. Bushman and L. P. Lehman, chemists at the sewage works, for the assistance rendered in the field and the laboratory work.

A Study of the Conditions Favoring "Bulking" of Activated Sludge

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Introduction.—Since the occasional bulking of activated sludge has become a well known and much dreaded fact, there is chiefly one cause to which the phenomenon has been attributed by most investigators, *i. e.*, underaeration, resulting in the excessive growth of protozoa and filamentous organisms of the cladothrix type, which, by their interwoven structure, diminish the settleability of the sludge. The remedy for this trouble was said to be found in prolonged aeration, or in killing the bulk of the protozoa, without affecting the bacteria of the sludge, which may be done by adding small amounts of certain dyestuffs, such as Meldola blue, in a concentration of 1 to 20,000.[1]

In later studies, however, stress was laid on the fact that sufficient aeration would not always prevent bulking, nor would abundant air supply eliminate the diseased sludge. Moreover, excessive and prolonged aeration is said to be the cause of the dispersal of sludge particles, so that settlement of the sludge is hampered, thus creating conditions resembling the real bulking phenomenon.

In 1928 Kolkwitz[2] stated that the trouble was the result of a lack of equilibrium between the absorptive and the regenerative power of the sludge, indicated by the development of *sphaerotilus*, which disappears again as soon as the equilibrium is re-established. In other words, overloading of the sludge is the cause of bulking and there are no special constituents of the sewage that could be labeled as especially guilty.

W. Scott[3] was one of the first investigators to deny the exclusive influence of aeration and to emphasize the preponderating influence of certain substances in the sewage. He pointed out that the damage done by milk wastes cannot be cured by suitable aeration. A few years before, Kessener, describing his experiments at a milk factory at Vorden (Holland),[4] had ascribed the heavy bulking of the activated sludge solely to underaeration. Scott states that starch in the proportion of 1 per cent, and also brewery waste, formed a very effective means of promoting the bulking. Likewise Bach, in his letter to the Editor of the *Surveyor*,[5] emphasizes his view that carbohydrates are the chief cause of bulking, because they promote the growth of filamentous organisms belonging to the genus *sphaerotilus*. The same conclusion is drawn by Morgan and Beck[6] and by Ruchhoft and Watkins,[7] who, in their very interesting study on the bulking of sludge of the Des Plaines River Plant, of the

Sanitary District of Chicago, were able to isolate the causative organism in pure culture and to investigate the conditions of its growth.[7]

In reviewing the limited knowledge of the phenomenon cited above, it seemed worth while to make a renewed study of its causes.

Experimental.—Assuming that carbohydrates are the cause of bulking, the quantity and quality of sugar necessary and sufficient to produce the phenomenon had to be estimated. Furthermore, the occurrence of "sugar" in sewages causing bulking should be stated, its quantity determined and a means of eliminating its noxious properties should be considered. And thirdly, are carbohydrates the only substances to be con-

FIG. 1.—Normal Activated Sludge. Magn. 68.

sidered, or are there still others that may be held responsible for similar phenomena?

Effect of Carbohydrates.—With the above points in view, series of experiments were made, partly in a small-scale experimental plant built at the Laboratory of Hygiene, partly using glass cylinders of 2-liter capacity, air being blown in at the bottom by means of glass diffusers. Only fill-and-draw experiments being possible in the last named way, the experimental plant provided means of continuous flow studies, the sewage used being that produced in the animal house of the laboratory. The plant consists of an iron tank of 300-liter capacity, which can be filled with the sewage by a centrifugal pump. From this it flows by

TABLE I

PURIFICATION OF NORMAL SEWAGE IN SIX HOURS' CONTINUOUS FLOW

	Permanganate.	NH_3	P. p. m. NO_2	NO_3	pH	Number Bacteria	Reduction, %	*B. coli* per Cc.	Reduction, %
Raw Sewage	164	19.3	0	0	7.0	1,030,000	..	100,000	..
1st Compartment	51.9	1.24	1.9	44.5	7.1	.....	..	.....	..
2nd Compartment	38.0	0	0.8	44.5	7.2	.....	..	.....	..
3rd Compartment	25.3	0	0.07	59	7.2	.....	..	.....	..
Settled Effluent	29.1	0	0	80	7.2	6,200	99.4	1,000	99

gravity to the aeration tank, equally of 300-liter capacity and divided into three compartments, through which the sewage and sludge mixture

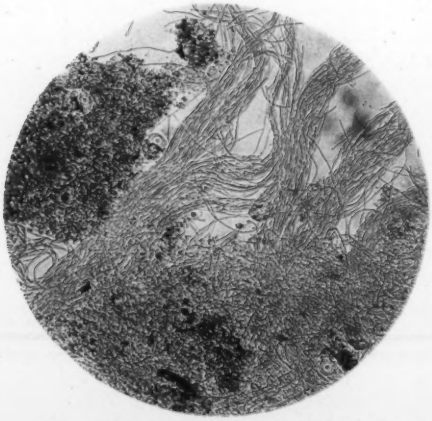

FIG. 2.—Heavily Bulking Sludge. Magn. 92.

has to pass in succession. The sludge settles in a settling tank, from which the clear water flows off into the sewer, while the sludge is pumped back by air-lift to a small mixing tank at the beginning of the installation, where it is mixed with the incoming sewage. The mixture is aerated by three diffusers lying alongside one of the walls of the aeration chamber. When sufficient sludge was built up, a continuous inflow of 50 l. per hour (6-hour detention period) proved to be purified to a very high degree, as shown in Table I.

Glucose.—In the first place the influence of small amounts of sugar (glucose) on the behavior of this plant was investigated. It was proved that 100 p. p. m. of sugar was decomposed without difficulty, the pH of

the mixture in all compartments remaining at 7.2 while sugar was to be found only in the first compartment. The behavior and the microscopical appearance of the sludge remained unchanged. We then proceeded to raise the amount of sugar (technical glucose) to 1000 p. p. m. during the day hours from 9 to 5. It was found that 4 hours after the beginning, sugar could be traced in the first two compartments, and after 7 hours in all three. But 5 hours after the addition was stopped, sugar was absent in all compartments. After one day a small amount of filamentous organisms appeared in the sludge, without, as yet, doing any harm. The pH remained at 7.0. During the next ten days the rate of decomposition of sugar increased considerably, after the 6th day only the mixture in the first compartment giving a positive reaction. pH gradually rose to 7.2 and scum formation was seen in the first two compartments. When seen under the microscope the sludge had altered in some ways, resulting in more threads and disappearance of *Vorticella*. After discontinuing the addition of sugar during 3 days, it was started again and then in 3 more days a very severe bulking of the sludge manifested itself: the usual straw color and a very slow settling rate were the chief characteristics, the threads had increased enormously, flagellates and the hypotrich ciliate *Euplotes* appeared (Figures 1 and 2).

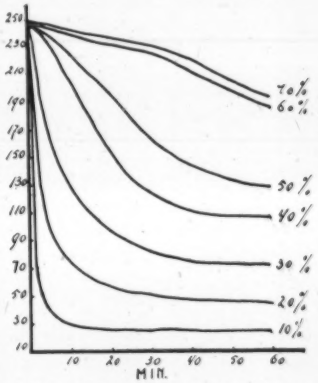

FIG. 3.—Settlement Curves of Different Mixtures of Sludge and Water.

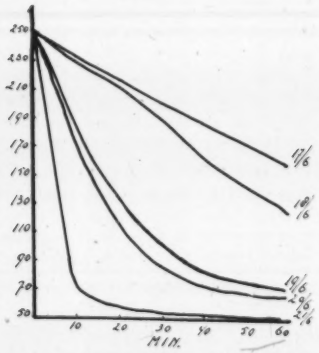

FIG. 4.—Restoration of Settling Properties by Aeration with Sugar-Free Sewage.

Quantitative Estimation of Bulking Properties.—In order to estimate the settling of the sludge quantitatively, the following procedure was adopted and gave much satisfaction. All experi-

ments were begun with a quantity of 10 per cent of well-activated sludge in the aeration tank. In the course of the experiment the volume of sludge gradually increased parallel with its water content, the sewage itself being so weak that no appreciable growth could be detected during this time, when no sugar was added. The mixture of water and sludge was settled daily in a glass cylinder of 250-cc. capacity, and the volume of settled sludge was read, at first, after 10, 20, 30, 40 and 50 minutes, afterward at longer intervals. The readings were plotted into a diagram, producing a settlement curve of characteristic form, corresponding with that of a water-and-sludge mixture containing a much higher initial concentration of normal sludge. The settlement curves of different concentrations of normal sludge are plotted in Figure 3.

The data obtained at the time of severe bulking (June 17th) were as follows:

Time, Minutes	Volume, Cc.
0	250
10	232
20	215
30	200
40	186
55	164
70	142
100	109
130	94
190	92

These results are plotted as the top curve of Figure 4, having nearly the same shape as the 55 per cent curve of normal sludge.

Normal operation was now continued, but without addition of sugar. The way in which the curves changed in the course of the following days is demonstrated by the lower curves of Figure 4, demonstrating the rather quick restoration of settling properties of the sludge. Indeed, on June 23rd the sedimentation curve again shows its normal aspect, the color of the sludge has darkened, *vorticella* has reappeared.

It may be concluded from these experiments that as much sugar as 0.1 per cent can be broken down by a continuous-flow treatment during a short time, but not without the sludge soon becoming completely spoiled by a severe bulking, so that the operation of the plant has to be discontinued. The products of the sugar metabolism are not yet found; contrary to my expectation, acids could not be traced, pH remaining at the same level throughout the experiments. Further investigations will have to decide whether all of the sugar has been burnt to carbonic acid and water or still other products are formed.

A similar series of experiments was begun with half the amount of sugar added to the sewage, *viz.*, 500 p. p. m.

It was shown that this quantity was easily digested during the 3 weeks' experiment, so that only in the first aeration compartment could sugar be traced, notwithstanding the fact that in a few days the filamentous organisms in the sludge increased very strongly, and the color turned to a yellowish brown. However, *vorticella* remained to the last and the bulking, which accompanied the development of the threads, came to a maximum, which allowed of a fairly good manipulation of the plant and the production of a well nitrified and stable effluent. pH remained between 7.2 and 7.4. After the addition of sugar was discontinued, the sludge regained its healthy and normal brown appearance in 10 days, the threads strongly decreasing, and the settleability increasing to the normal value.

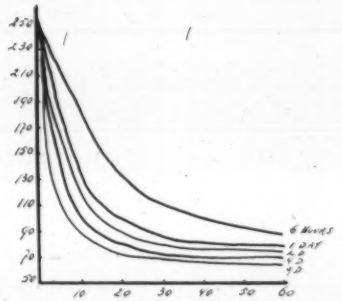

FIG. 5.—Slow Improvement of the Sludge by Prolonged Aeration of the Same Sludge-and-Water Mixture.

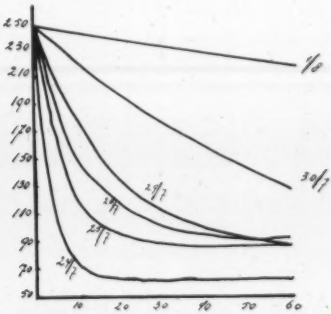

FIG. 6.—Bulking Produced by Addition of 0.05 Per Cent Sucrose in 8 Days.

The fact was observed that this regeneration can be accomplished only when fresh sewage is added to the sludge periodically (say once every 24 hours). Prolonged aeration of the same mixture of sewage and sludge, without renewing the former, leaves the sludge straw-colored, although its settling capacity improves (Figure 5).

A new series of experiments with 300 p. p. m. of glucose brought little new information. Only a moderate bulking occurred, the color of the sludge remained a dark brown and only a few threads developed, *vorticella* and *carchesium* being abundant. The sugar was easily digested.

Sucrose.—The question arose whether the influence of sucrose would be the same as that of glucose. To answer this, experiments were started, using the same sewage as before, with the addition of 500 p. p. m. of sucrose, and the same sludge after its complete restoration from the treatment with glucose.

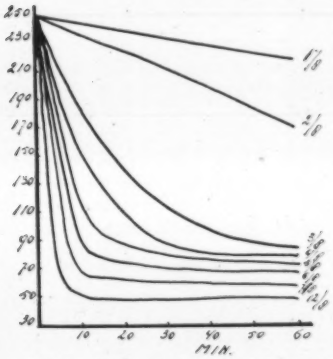

FIG. 7.—Restoration of the Sludge of Fig. 6 by Treatment with Sugar-Free Sewage in 12 Days.

The phenomena produced were similar in all respects to those of the former series. Within four days bulking appeared to such an extent that after 8 days the sugar addition had to be stopped (Figure 6). During this time the sugar added was quickly and completely digested, and in no instance could the presence of reducing sugar be traced, neither in the first compartment, where sucrose could be found (reduction of Fehling's solution after heating with diluted acid) nor in the others, proving that the sucrose is digested without previous inversion, or that the digestion of the glucose and fructose proceeds at a faster rate than inversion of the sucrose. The pH remained at 7.2.

After discontinuing addition of sugar the sludge was restored in 6 days, the threads gradually disappearing (Figure 7).

Lactose.—Similar experiments with 1000 p. p. m. lactose again showed corresponding results: heavy bulking followed by a gradual restoration after the sugar addition was stopped.

Starch.—Experiments with starch promised to be of peculiar interest, since Scott, in his paper cited above, has shown the deleterious effect of this carbohydrate.

Starting with small scale experiments in glass cylinders, we were astonished to find that 500

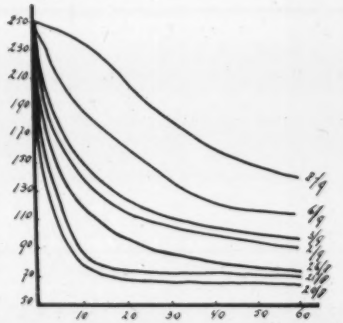

FIG. 8.—Bulking Produced by 0.2 Per Cent Starch in 19 Days.

p. p. m. of soluble starch was digested in something more than 4 hours, and that the same amount (dissolved in fresh sewage) could be added twice a day to the sludge without causing any change: the color remained dark brown and the settlement curve showed no alteration. *Vorticella* remained abundant and filamentous organisms showed no appreciable growth. After 5 days starch was added three times a day. After $1^1/_2$ hours' aeration iodine no longer caused a blue but a violet coloration, typical for dextrin. In each 6 hours aeration period the starch proved to be completely digested, without reducing sugar being traced. Nitrification of the sewage nitrogen was nearly complete, as in normal cases, and pH remained stationary.

Then the amount of starch was increased to 1000 p. p. m., being added twice a day. But no bulking manifested itself and the sludge remained well activated. On the contrary, the digestion of the starch was effected at an increasing rate, so that after a few days' treatment the iodine reaction was negative after 1 hour's aeration. *Sphaerotilus* did not develop.

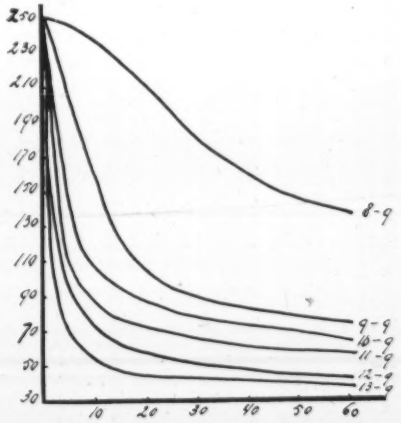

FIG. 9.—Restoration of the Same Sludge Without Starch in 5 Days.

Only when the starch dose was again increased to 2000 p. p. m., did a change become apparent. The settleability of the sludge decreased (Figure 8), its color turned to a light brown, the starch was not completely digested in 8 to 9 hours and the liquid remained very turbid. After 18 days the addition of starch was stopped, fresh sewage being added twice a day. Thereby a remarkably quick regeneration occurred, the sludge regaining its normal properties in 5 days (Figure 9).

After these experiments were completed, continuous-flow experiments seemed advisable in order to check the laboratory results under conditions resembling actual plant operation. The experimental plant described above was again used, a 2 per cent solution of soluble starch being continuously added to the fresh sewage at the rate of 50 cc. (1 gr. of starch) per liter.

The result was disappointing, inasmuch as bulking set in after a week and remained for 17 days, when the starch addition was stopped. Nevertheless the starch added was completely used up, indicated by the reaction with iodine, and the gradual splitting of the starch could be traced without difficulty throughout the installation, this reaction changing from blue at the influent to colorless or faintly red at the effluent. The change in pH was never more than 0.2 (from 7.6 to 7.4).

A new experimental series established the fact that doses of 100, 150 and 200 mg. per l. of starch were digested during a few weeks' period without causing bulking, starch or sugar being untraceable in the second and third compartment of the installation.

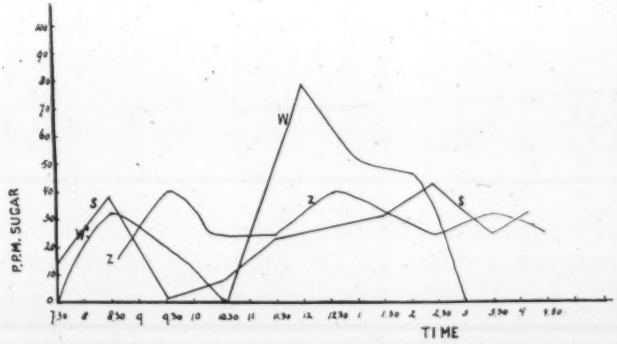

FIG. 10.—Sugar Content of Different Amsterdam Sewages During Daytime. S = Sewage Works West. Z = Sewage of Amsterdam South and East (Central Sewer). W = Sewage Works East.

The deleterious effect of carbohydrates now being quantitatively established, the question presented itself as to whether the amount of sugar in domestic sewage could be held responsible for bulking of sludge in activated-sludge plants.

The Occurrence of Carbohydrates in Sewage.—So far as the writer is aware, the occurrence of carbohydrates in domestic sewage has never been investigated, apparently because the quantity of sugar was thought to be so small as to be unable to do any harm. Only in a few cases, cited above, where industrial wastes from sugar or starch factories, distilleries, etc., could be traced as the cause of bulking, has it been the object of research.

When one considers the domestic origin of ordinary sewage, especially

where a separate sewerage system is used, and consequently no storm water enters the sewers, the presence of limited quantities of sugar and starch should be deemed a normal fact. Without doubt, part of the sugar used is washed away and its concentration in sewage is therefore governed by three circumstances: the quantity of sugar wasted, the flow of sewage per head and the digestion of the sugar in the sewage by the action of bacteria before it reaches the sewage works.

The Amount of Sugar in Sewage.—The amount of sugar discharged is difficult to estimate and may vary considerably according to the habits of the population. Conditions in Holland seem to be such that the middle

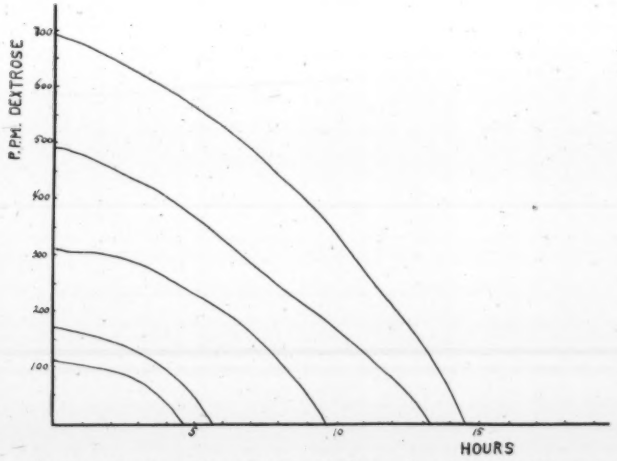

FIG. 11.—Digestion of Sugar (Dextrose) in Sewage from the Central Sewer.

and lower classes give off more sugar to the sewage than those better situated. The habit of washing coffee and teacups containing a large residue of undissolved sugar seems to be more frequent in the former part of the population, and may account for part of the sugar content of domestic sewage. It will be evident that the amount is highly variable during the day and falls off to zero during the night hours. Besides, most of the weekly household washing being done at home, starch is given off to the sewage on washing days along with a large amount of soap. Especially in the districts of Amsterdam West and East this washing day can easily be detected by the character of the sewage. The district of

Amsterdam South along with the larger part of East have a separate sewerage system, from which the sewage is pumped into the former Zuider Zee. The smaller part of East has its own sewage plant, consisting of Imhoff tanks (Francke type) and bacteria beds, completed by secondary settlement, so that the effluent can be discharged into a polder canal without causing trouble. The district of West has a similar sewage plant, which during later years has become heavily overloaded, due to the considerable extension of this part of the city. The flow of sewage per capita is extremely low (8 to 16 gallons) so that the sewage is of an exceptionally strong character. It is pumped through a pipe line $1^1/_2$ miles long before it reaches the sewage works. The central sewer of the south and east

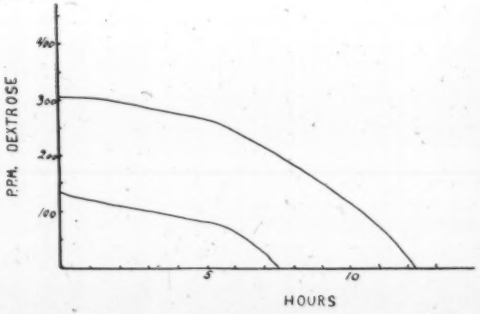

FIG. 12.—Digestion of Sugar in Sewage of Amsterdam West.

district, which carries the sewage to a large pumping station, where it is pumped 3 mi. into the sea, has a length of about 10 mi., while that of the small eastern district leading to the sewage works is only 0.6 mi. long.

The sugar contents of the different Amsterdam sewages are plotted in the curves of Figure 10.

These curves indicate that the amount of sugar would by no means be sufficient to produce a severe bulking of activated sludge. In other places, where the sewage flow per head is usually much greater and perhaps the wasting of sugar is less, there is certainly no possibility of sugar being the cause of bulking under normal conditions.

The Digestion of Sugar in Sewage.—It may be assumed that when sugar or starch is mixed with domestic sewage the large numbers of bacteria present therein will attack the carbohydrate so that its quantity will tend to decrease. Meanwhile organic acids are formed, which combine with the alkalies. This metabolism will proceed quickly or slowly according

to the temperature and the composition of the sewage. Experiments on the velocity of this reaction, when Amsterdam sewage was used, gave the following results. Sewage of the central (south and east) sewer, containing some 40 p. p. m. of reducing sugars, was dosed with amounts of glucose varying from 100 to 700 p. p. m. and stored at room temperature (16° C.). The sugar proved to be used up after from 5 to 15 hours. In the exceptionally strong sewage of Amsterdam West, containing considerable amounts of hydrogen sulphide, the splitting proved to be materially slower, while that of Amsterdam East, non-septic, behaved nearly like that of Amsterdam Central.

The data are plotted in the curves of Figures 11, 12 and 13.

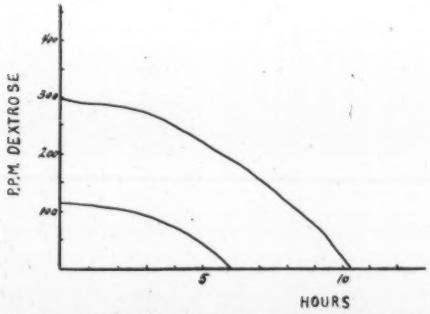

FIG. 13.—Digestion of Sugar in Sewage of Amsterdam East.

Conclusions

The phenomenon of bulking of activated sludge has proved to be materially influenced by the presence of carbohydrates. It is shown that glucose, sucrose and lactose are particularly deleterious, while the influence of starch is much less. Notwithstanding the deterioration of the sludge, the carbohydrates are digested with rapidity. After the addition is stopped, renewing of sugar-free sewage being continued, a quick restoration of the sludge occurs, whereby the settleability of the sludge again reaches its original value.

A method for quantitative estimation of settling properties is indicated. The occurrence of carbohydrates in sewage is discussed and it is shown that the sugar content of Amsterdam sewages is far below the limit of harmfulness.

It follows from the above specifications that the real cause of bulking in domestic sewages must lie elsewhere. Experiments on this point as

well as on the causative organisms of bulking will form the subject of a future communication.

In concluding the writer wishes to acknowledge the intelligent assistance of his co-workers, Dr. L. Louwe Kooymans and Mr. W. Kauffmann.

References

[1] Fairbrother and Renshaw, *J. Soc. Chem. Ind.*, **41**, 134T (1922). Harris, *et al.*, *Surveyor*, **70**, 30 and 55 (1926).

[2] Kolkwitz, *Ber. d. d. bot. Gesellsch.*, **46**, 35 (1928).

[3] W. Scott, "The Bulking of Activated Sludge," *Surveyor*, **73**, 345 (1928).

[4] Kessener, *Transact. Int. San. Conference, London*, **1924.**

[5] *Surveyor*, **75**, 264 (1929).

[6] Morgan and Beck, THIS JOURNAL, **1**, 46 (1928).

[7] Ruchhoft and Watkins, *Ibid.*, **1**, 52 (1928).

The Anaerobic Stabilization of Sewage Screenings

BY C. S. BORUFF AND A. M. BUSWELL

State Water Survey, Urbana, Illinois

During the past year sanitarians have given considerable attention to the treatment and ultimate disposal of sewage screenings. Although screenings represent a rather minor position in relation to the total weight of solids collected and treated at a sewage treatment plant, their disposal demands considerable attention. Screenings are normally composed of sewage-soaked paper, rags, garbage, sticks, matches, vegetable matter, etc., mixed with fecal matter and sewage "grease." Industrial wastes may add other types of materials. The character of the screenings also depends on whether the sewers are of the separate or combined type, on the character of the population or industries served, and on the season of the year. The size of openings of the bar racks or screens and the method and frequency of cleaning also affect the character and quantity of screenings recovered. As noted in Table I, bar screens remove an average of about 2 cubic feet (100 lb.) of screenings of about 85 per cent moisture, or 15 pounds dry weight of material, per million gallons. Fine screens, depending on the type and size of openings, remove from 5 to 40 cubic feet of screenings, or about 50 to 400 pounds dry weight of materials per million gallons. For additional data see Flood.[5] Although the above weights may seem immaterial, simple calculations will show that in moderately large plants (20 m. g. d. or so) there are collected from 50 to 700 tons, dry weight, of screenings per year. These screenings may be infected with pathogenic bacteria, and they contain sufficient putrescible material so that they soon become very foul and offensive unless they are dried, treated with lime or other chemicals to arrest putrefaction, or disposed of in some manner.

The common practice at most plants is to bury the screenings or use them for fill. In a very few places they are used for fertilizing purposes. In regard to cost, some plants report disposal as cheap as 50 cents per ton, while others find the expense runs as high as $9.30 per ton.[16]

Burial requires considerable waste land. Many operators have come to realize that soon they will have used all their spare land for this purpose. Many have reported that when they uncovered screenings which had been buried for a year or more, they found them to be only slightly decomposed and more offensive than when they were originally buried. They were in such bad condition that it was found undesirable to stir up the ground and bury more screenings at the same place. Such deposits are a potential if not an actual source of odors and fly nuisances.

Disposal by incineration with its numerous problems has been given consideration by many plants.[11,12,13] Such a method involves handling

difficulties, the partial drying of the screenings by heat or pressure (press or centrifuge), followed by subsequent burning with gas, oil, coal or other fuel. Unless special care and special burners are used, such a method of disposal is a continuous source of annoyance. Odors are common. The first cost and operating costs are high. Townsend[12] has estimated that it will require 15 gallons of oil (150,000 B. t. u. per gal.) to incinerate 1 ton of Milwaukee's semi-dried screenings (65% moisture). This fuel will cost between 75 cents and a dollar per ton of screenings. Interest, depreciation, maintenance and labor charges may be expected to add another dollar to bring the total cost of disposal to between $1.75 and $2.00 per ton. The screenings-grit incineration plant which is designed for a 1940 flow of 139

TABLE I

QUANTITY OF SCREENINGS RECOVERED FROM SEWAGE

Plant	Reference No.	Type of Screen	Size of Openings, In.	Quantity per Million Gallons		
				Cu. Ft.	Lb. Wet Weight	Moisture, %	Lb. Dry Weight
Bar Screens:							
Average	5			0.5 -2.0			
Grand Rapids, Mich.	*	Incl. rack	1 1/2	0.6			
Milwaukee, Wis.	12	Incl. rack	3/4	2.0	150	88	18
Hanover, Pa.	17	Rack	1 1/2	2.0			
Plainfield, N. J.	*	Incl. rack	1/2	5.7	261	84	42
Worcester, Mass.	3	Incl. rack	2	1.8	121		
Aurora, Illinois	10	Incl. rack	1 1/4	0.8	52	81	9
Aurora, Illinois	10*	Incl. rack	1/2	1.4	77	86	11
Indianapolis, Ind.	16		1 1/4	0.5			
Dayton, Ohio	11			2.3	132	64	48
Urbana-Champaign	*	Incl. rack	1 9/16	1.0			
Baltimore, Md.	7		7/8	1.9	100	81	19
Decatur, Illinois	*	Incl. rack	1 9/16	0.3 -0.5			
Fine Screens:							
Average	5			5.0-30.			
Plainfield, N. J.	*	Reinsch-Wurl	1/16	21.	1,323	88	159
Milwaukee, Wis.	12	Tark	3/32	14.	975	92	78
Long Beach, Cal.	*	Dorr Co.	1/16	40.	1,960	80	392
South Yonkers, N. Y.	13	Reinsch-Wurl	1/16		1,000+	90	100+
Baltimore, Md.	*			7.	467	86	65

* Private communication.

m. g. d. will cost $121,071. Tatlock[11] reports that at Dayton, Ohio, it requires 4.4 cubic feet of gas per pound of pressed screenings (64% moisture) or 32 cents per million gallons of sewage to burn the screenings. He estimates the total cost for fuel, labor and repairs to be 75 cents per million gallons. At Long Beach, California,[5,14] it costs $1.06 per million gallons or $1.00 per ton (wet weight) to burn the fine screenings. It requires 106 cubic feet of gas (1150 B. t. u.) per cubic foot of wet material (1.5 cu. ft. per lb., 90–92% moisture). At South Yonkers, N. Y., it requires 25 gallons of fuel oil per ton of bar and fine screenings (80% moisture).[13] Gascoigne[6] reports that centrifuged screenings, containing 65 per cent moisture, require about 25 per cent of coal by weight for incineration. At Baltimore, Keefer[7] found it required an average of 11.1 pounds of bituminous coal

to burn 1.0 cubic foot or 50 pounds of pressed screenings (72% moisture). Apparently, it requires 2000 to 3500 B. t. u. to incinerate 1.0 pound of wet screenings.[5]

Where adequate digestion capacity is provided screenings are added to sludge digesters (Ipswich, England; Hanover, Pa.; Moscow, Russia).[15,17] If scum troubles are experienced in digestion tanks it is not advisable to add screenings, because they tend to collect in the scum and form a very thick and tough mat at the surface. As the result of experimental runs Keefer[7] has concluded that pressing plus incineration is more economical than maceration plus digestion with sewage solids.

Reports have also been made on the composting of sewage screenings in open pits or cells. At the Tenafly (N. J.), plant fine screenings have been composted by molds. The compost cells are cleaned out once a year. The process is reported not to be particularly offensive.[4] Rawn[8] recently reported studies made by the County Sanitation Districts of Los Angeles on the composting of screenings in two open pits (12.5 ft. square by 10 ft. deep). He found that he could treat screenings and skimmings in such pits at the rate of 20 to 25 cubic feet per day (probably 175 lb. dry weight per day; 112 lb. dry weight per day per 1000 cu. ft. of tank capacity). He advises sufficient capacity for a 60-day digestion in the presence of 50 per cent by volume of seeding material (sludge). Rawn encountered serious scum troubles in his pits and was unable to circulate or remove the digested or composted materials from the pits with pumps. Gas recovery was not practised. One of the pits went sour and produced a "soury pig-pen odor."

The results of the large scale experiments conducted at Milwaukee on the digestion of sewage screenings have been briefly described by Townsend,[12] and in detail by Rudolfs and Heisig.[9] These investigators found it biologically possible to stabilize screenings anaerobically, but they met with operating difficulties due to the collection of all of the fermenting material at the top of the digester in a tough, thick mat. It was difficult to feed the tanks and impossible to draw digested residue when desired. A special scum saturator aided somewhat, but this method of disposal was finally abandoned on account of the mechanical difficulties encountered. Townsend writes as follows, "Usually the termination of the several different sets of tests was more or less automatic in principle, the digestion compartments having become so overburdened with materials of an indigestible character as to interfere seriously with the uniformity in the rate of gas production." In spite of these difficulties, it was possible to operate one digester (6750 cu. ft. capacity) for 241 days. It was fed at an average rate of 55 cubic feet, or 275 pounds dry weight of screenings per day (123 cubic feet of tank capacity per cubic foot of screenings added per day or 41 pounds dry weight of screenings per 1000 cubic feet of tank capacity).

From this material 5.7 cubic feet of gas was recovered per pound dry weight of screenings added. Prüss* has reported favorably on the digestion of fine screenings at Magdeburg, Germany. Violent circulation of sludge from the bottom of the digester into the surface scum and mat has been found satisfactory. Ten liters of digestion capacity (0.35 cu. ft.) are provided per capita. The recovered gas contains 60.8 per cent methane.[18]

Experimental

The present writers, like many of the earlier workers who investigated the anaerobic fermentation of cellulose and cellulosic materials, have noted the mechanical and biological difficulties involved in trying to produce a well-regulated and dependable digestion of fibrous materials such as crude plant tissue, sewage screenings, paunch manures and the like. As soon as the material starts to ferment, gas bubbles become trapped in the fibrous structure and the entire mass of the fermenting material is buoyed to the top of the tank or container. If this mat is not broken up, the rate of gas recovery is quite variable and there is a marked tendency for the fermentation to turn sour. If, however, the mat is broken up intermittently or continuously in some manner, the entrapped gases are liberated, the gasification continues at a uniform rate and the continuous operation of the tank is assured. Motor-driven paddle stirrers and the circulation of moderate volumes of tank liquor over the accumulated mat were found ineffective. Many possible tank designs were suggested and investigated by the authors, but the one shown in Figure 1 is the one that has been found most successful. Additional information concerning the development of this special drum type of digester for fibrous materials may be found elsewhere.[2]

The tank is of rectangular shape and provided with a transversely extending vertical baffle A, spaced from one end to divide the tank into two compartments, a relatively large digestion compartment and a smaller residue compartment.

A cylindrical drum is mounted horizontally within the digestion compartment upon a shaft journalled in bearings carried by the wall A and end wall of the tank. The drum is adapted to be rotated continuously or intermittently at any suitable speed. The frame of the drum is covered with a cylinder of reticular material, such as wire screening or perforated metal. Each end of the drum is provided with a seal ring which is adjusted so as to prevent the escape of material from within the drum into the outer portion of the fermentation compartment.

The feeding end of the tank is provided with a spout extending through an opening in the tank end wall within the circle formed by the seal ring.

* Private Communication, Dr. Max Prüss, Emschergenossenschaft, Essen, Germany.

The material to be treated may thus be fed directly into the open end of the drum adjacent to the feeding spout. A discharge opening is provided in the lower portion of the baffle wall A to permit stabilized material from the drum to pass out into the discharge compartment. Material discharged into the compartment is withdrawn in any suitable and convenient manner.

The fermentation compartment is fitted with a gas-tight cover provided with a gas vent having a tight cover, or a removable hood resting in a water seal. The water seal prevents the entrance of air into the digestion compartment where the fermentation takes place and also the escape of gas. It likewise prevents the building up of excessive pressures within the digestion chamber and tends to keep a uniform, slight pressure therein. A pipe from the collecting hood serves to draw out the gas into a suitable reservoir or any device in which the gas may be used or stored.

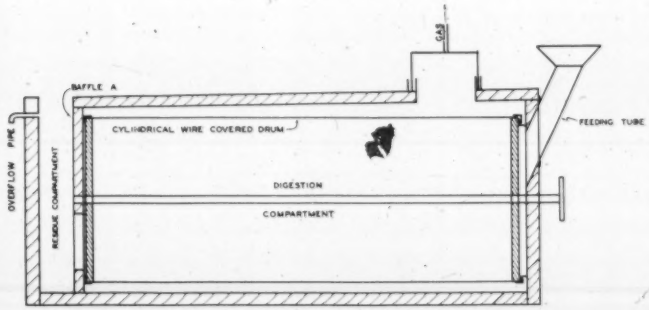

FIG. 1.—Digester for Fibrous Materials.

The drum is rotated or inverted at least twice a day, or continuously, if desired. This releases the entrapped gases and the tank contents are sufficiently mixed to prevent local accumulation of acids. The writers have found the turning over of the drum and the periodic feeding at the front end of the tank to be sufficient to cause the fermented material to work itself out through the opening in the baffle into the residue end of the tank. Here it continues to ferment slowly and again gas bubbles are entrapped and the material is brought to the surface where it can be removed with a hay or manure fork or by a continuous device if desired. The design and operation of this drum type digester has been patented by the writers (Buswell and Boruff, U. S. 1,880,772, Oct. 4, 1932).

The writers have constructed three pilot units according to the design shown in Figure 1. One 1287 gallon tank, 172 cu. ft., has been operating since June, 1930. Another 1376 gallon tank, 184 cu. ft., has been in

use since November, 1930. These two tanks have been operated successfully on straw, cornstalks, stable manure, extracted Jerusalem artichokes and a combination of straw and undiluted whey waste. Another smaller unit, 92 gallon, 12.3 cu. ft., has been operating since December, 1931. For six months it operated successfully on bar screenings from the Urbana-Champaign sewage plant. It is now being operated on packinghouse screenings and paunch manure.[1]

On the basis of numerous laboratory studies and the successful operation of these three pilot unit tanks, the authors feel that a solution to the problem of the fermentation of fibrous materials such as crude plant tissue, sewage screenings and the like has been found. A brief summary of all of the pilot unit experimental data has been presented elsewhere.[1,2]

The 12.3 cubic foot digester, which contained a drum 20 inches in diameter and 42 inches long (7.6 cu. ft_i) was operated for 6 months on bar screenings from the Urbana-Champaign treatment plant. During the first 3 months numerous experimental operations were investigated. Among other things it was noted that to insure the proper fermentation it was advisable to start the tank with residue from another such tank or to use digested sludge as the inoculum (10% by volume), and to feed slowly at first in order that the volatile acids will not reach a concentration of

TABLE II

THE ANAEROBIC DIGESTION OF SEWAGE SCREENINGS*

Pilot Unit Digester, 12.3 Cu. Ft. Capacity; 25–30° C.

	1932		
	March	April	May
Screenings Fed:			
Wet Weight, Lb.	618	774	583
Dry Weight, Lb.	77.0	88.1	61.9
Gas Recovered:			
Total Volume, Cu. Ft.	397	440	397
Weight, Lb.	29.8	34.3	28.4
Average CH_4, %	60	56	61
Residue Drawn:			
Wet Weight, Lb.	180	150	419**
Dry Weight, Lb.	28.3	48.0	63.1**
Summary of Capacity Data			
	Per Thousand Cu. Ft. of Tank Capacity		
Screenings Fed per Day:			
Wet Weight, Lb.	1620	2100	1530
Dry Weight, Lb.	200	239	163
Gas Recovered per Day, Cu. Ft.	1040	1195	1040

* Bar Screenings from Urbana-Champaign sewage plant.

** Includes residue removed from drum at end of month when tank was cleaned out to start other experiments.

over 1500 to 2000 p. p. m. as acetic acid. After the tank has started to ferment normally, the amount of screenings fed per day can be gradually increased up to the normal operating capacity, namely, about 200 pounds dry weight per day per 1000 cubic feet of tank capacity. Once properly started no sludge, sewage liquors or chemicals need be added to control the fermentation of the screenings. It was found advisable to maintain the digestion temperature between 25° and 30° C. The data for three months of operation of this small pilot unit are given in Table II. During this period screenings were fed at the rate of from 1530 to 2100 pounds wet weight (163 to 239 lb. dry wt.) of screenings per day per 1000 cubic feet of tank capacity. In the investigations of Rawn[8] and Rudolfs and Heisig[9] they were able to feed at rates of only 112 pounds and 41 pounds dry weight, respectively, per day per 1000 cubic feet of tank capacity.

Gas was collected from the screenings at rates of from 1040 to 1195 cubic feet per day (average 1092) per 1000 cubic feet of tank capacity, or 5.45 cubic feet per pound dry weight of screenings added. The gas contained from 56 to 61 per cent CH_4 (average 59%) and hence had an average B. t. u. value of 590, which is about the same as coal gas, but as noted previously for cellulosic materials[3] is a little less than that collected from the digestion of other sewage solids.

It is the intent in this fermentation to digest and stabilize all of the putrescible materials found in sewage screenings. Such materials ferment much more rapidly than the major portion of the paper, rags, matches and other cellulosic constituents present. It would be impracticable to provide sufficient digestion space for complete digestion of these materials. Therefore, as in the digestion of sewage solids, the tanks are designed to retain the screenings only so long as is necessary to bring about the stabilization of the putrescible materials. The residue or material left, following the digestion of screenings fed at rates of from 163 to 239 pounds dry weight per day per 1000 cubic feet of digestion capacity, has been found to be inoffensive and non-putrescible. The residue is fibrous and as drawn from the residue compartment contains an average of about 85 per cent moisture. It dries very rapidly. A bucket full of the wet residue was brought into the office of the writers where it remained for two months. No odors were noted.

This residue could be drawn on sludge beds by itself or with digested sludge and hence dewatered and disposed of in the usual manner, or it could be drawn and used for filling purposes or piled in the open until it was dry enough to burn. As this material is non-offensive, non-putrescible, does not draw flies and dries rapidly, it could be dried and burned in the open. If piled or spread on the ground it slowly undergoes humification.

During the six months' experimental run on screenings no sludge was

deposited in the bottom of the rectangular tank. The sludge formed in the decomposition of the fecal matter in the screenings was so well mixed and distributed through the cellulosic materials that it was carried along with it into the residue compartment. The digestion of screenings in a digester of the type shown in Figure 1 can be carried on with the production of but little if any overflow liquor, for the residue removed from the tank contains practically the same amount of moisture as the screenings added. From a practical operating point of view, however, it would seem advisable to provide such a digester with a draw-off valve located in the bottom of the tank in order that any humus that might be deposited there over a long period of time could be withdrawn. It would also be advisable to provide for a small amount of overflow liquor. These liquors could be returned to the raw sewage. The make-up liquor, if and when needed, could be either raw sewage or water.

Plans are now being made to digest all of the bar screenings from the Urbana-Champaign sewage plant in a 184 cubic foot digester (Figure 1), which the authors have been operating on cornstalks, straw and manures.

Summary

A special drum type digester has been designed and operated. It has been found to overcome the difficulties encountered by the authors and many others when fibrous materials were subjected to fermentation. Sewage screenings fed at the rate of 1530 to 2100 pounds wet weight (163 to 239 lb. dry wt.) per day per 1000 cubic feet of digestion capacity have been stabilized, with the production of an average of 5.45 cubic feet of gas (59% CH_4) per pound dry weight of screenings added. This amounts to an average gas production of 1.09 volumes of gas per tank volume per day.

From a practical point of view, this means that the coarse-bar sewage screenings from a city of 50,000, equal to 5 cubic feet (38 lb. dry weight) or a little more per day, could be stabilized in a tank 4 ft. wide by 4 ft. 8 in. tall by 10 ft. long (187 cu. ft.). Such treatment would involve a low first cost and a low operating expense. From such treatment an average of 207 cubic feet of gas would be produced per day. If automatic screens were used or other sources of power were near by, connections could be made so that the digester could be fed automatically, the drum rotated continuously or intermittently and the residue removed.

References

[1] Boruff, Paper on "Stabilization of Packing-House Wastes" given at Denver meeting of American Chemical Society, August, 1932. (To be published in *Ind. Eng. Chem.*)

[2] Buswell and Boruff, Paper on "Mechanical Equipment for the Continuous Fermentation of Fibrous Materials" given at Denver meeting of American Chemical Society, August, 1932. (To be published in *Ind. Eng. Chem.*)

[3] Buswell and Boruff, THIS JOURNAL, **4,** 454 (1932).
[4] Donaldson, *Water Works and Sewerage*, **78,** 356 (1931).
[5] Flood, THIS JOURNAL, **3,** 223 (1931).
[6] Gascoigne, Report to Director of Public Service, Cleveland, Ohio, on "Treatment of Sewage from the Easterly Sewage District, 1931," p. 76.
[7] Keefer, *Proc.*, A. S. C. E., **55,** 1759 (Sept., 1929).
[8] Rawn, Paper on "Digestion of Bar Screenings" given before California Sewage Works Association, 1931.
[9] Rudolfs and Heisig, THIS JOURNAL, **1,** 519 (1929).
[10] Sperry, Paper on "The Plant Gas Fired Incinerator, Aurora, Illinois" given before Ill. Soc. of Eng. at Peoria, Ill., June, 1932.
[11] Tatlock, *Municipal Sanitation*, **2,** 428 (1931).
[12] Townsend, THIS JOURNAL, **4,** 509 (1932).
[13] Younge, *Water Works and Sewerage*, **79,** 191 (1932).
[14] Anonymous, *Ibid.*, **79,** 22 (1932).
[15] Anonymous, *Ibid.*, **79,** 287 (1932).
[16] Anonymous, *Municipal Sanitation*, **3,** 299 (1932).
[17] Anonymous, *Public Works*, **63,** No. 3, 21 (1932).
[18] Nadermann and Strümpfel, *Ges. Ing.*, **31** and **32,** (July 30 and Aug. 6, 1932).

Digestion of Bar Screenings*

BY A. M. RAWN

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Bar screenings, when compared with the aggregate mass of solids retained and treated at a sewage plant undertaking complete treatment, assume a position of relative unimportance. Specifically they may amount to from a half to five cubic feet per million gallons of flow, depending upon the rack openings and the time of concentration of the sewage at the plant. The average is about two cubic feet of material at 80 per cent moisture with dry solids content averaging twenty-five pounds per million gallons of 90 per cent non-putrescible material.

Small as this amount is, it assumes quite a total when equated to a continuous yearly flow. A yearly flow of one million gallons per day will yield 9100 pounds of dry bar screenings, or about twenty-seven cubic yards of wet. For the plant under consideration in this discussion, namely, that of the Los Angeles County Sanitation Districts, treating fourteen million gallons of sewage per day, this amounts to 127,000 pounds, or about 63 tons yearly of dry screenings, or the dry residue from 380 cubic yards of bar screenings, an amount which will increase annually at the rate of 15 tons and 88 cubic yards, respectively.

Common practice in most sewage disposal plants is to burn or bury such material, the former if adequate incineration facilities are convenient, and the latter if ground is available. Some, probably many, Imhoff tank operators dump the bar screenings directly into the tanks to digest with the rest of the mass, particularly if the tanks are not crowded. Continuous burying eventually takes up a lot of ground area, especially with large daily flows. Furthermore, constant vigilance is needed to eliminate the possibility of fly and odor nuisance in an open pit. Without good combustion, an incinerator is a continuous source of annoyance from the odor standpoint. These remarks are not intended in any sense to condemn either practice, but to draw attention to some of the inherent disadvantages of incineration or burying, which led the Sanitation Districts' engineers to an attempt to find an equally adequate and less inconvenient means of disposal.

Bar screenings differ from either fine screenings or material from primary settling tanks, in that while they contain a definite amount of putrefactive material, such is not their principal constituent. They are made up largely of sewage soaked paper, rags, waste, sticks, and vegetable matter, with occasional dead animals and some large chunks of packinghouse waste. Left to itself, a mass of bar screenings will readily putrefy, create odors and

* *Presented before the Fourth Spring Conference of the California Sewage Works Association, Yosemite National Park, California, May 21, 1932.*

breed flies, before it has had time to dry on a sand drying bed. Nevertheless, if the readily putrefactive material can be removed, the remaining portion will drain promptly and dry without odor, even though the most resistant particles therein have not lost their identity.

It may be that because the bar screenings do not occupy a relatively important position in the aggregate total of sewage solids to be cared for at a treatment plant, also that burial, or incineration, can be accomplished quite readily, and because the disposal of such material does not bulk large in the general problem which besets the sewage plant operator, there has been very little improvement in the method of bar screenings disposal since the first bar screens were installed ahead of pumps. A search of the literature relating to this subject discloses that while fine screenings were digested with indifferent success at Milwaukee, no other plant is on record as having attempted any method of screenings disposal other than by burying, barging to sea or incineration.*

The plant under discussion is unique in some respects. It is located within a half mile of a large number of middle-class dwellings, toward which a breeze, of varying intensity, blows for about twenty hours out of the twenty-four. Therefore, odors must be very carefully guarded against, and the incineration of any material taken from the sewage must be carried to such complete combustion that only the very best and most expensive type of incinerator would be adequate for the purpose of burning bar screenings. The soil upon which the plant is located is a very compact, impervious, black clay which has little sub-surface drainability. Screenings which have been buried for a period of four years show little, if any, deterioration. They are, when uncovered, almost exactly in the same form as when placed in the pits, and for the four years of plant operation, during three years of which screenings and skimmings have had to be buried, a rather large area has been utilized for such purpose without any hope of its similar re-use for a number of years to come. The plant now provides facilities for the digestion of the tank skimmings, mixed in with primary clarifier and activated sludge, so there remains only the adequate disposal of bar screenings.

Carrying out the thought that bar screenings once washed of their putrescible material would dry without nuisance, the Districts arranged and completed the following experiment.

Two open pits were dug in the tight clay soil. Each was about twelve and one-half feet square by ten feet deep with sides sloping slightly. They were simply unlined open pits and were left uncovered during the trial. No equipment for heat control or for pumping was installed in either.

From the sludge digestion tanks of the main plant a quantity of sludge which had about completed digestion was pumped into each pit. Forty per cent of Pit No. 1 was filled with such material, and sixty per cent of

* *Editor's Note.*—See, however, the paper by Buswell and Boruff, this issue, p. 973.

Pit No. 2. The digested sludge contained 96 per cent moisture and the dry material contained 48 per cent volatile matter.

The pits were then filled to capacity with tank skimmings and bar screenings at the rate of 25 cubic feet of bar screenings and 80 cubic feet of skimmings a day, divided proportionately between the pits. This operation required twelve to fifteen days. At the expiration of the time consumed in filling to capacity, Pit No. 1 with 40 per cent seed had turned acid, almost entirely ceased gassing and gave off a sour pig-pen odor. It was blanketed with a dry, thick scum, difficult to break up and had the general appearance and odor of acid fermentation. On the contrary, Pit No. 2, with 60 per cent seed, although covered with a similar scum, was digesting nicely, giving off the characteristic odors of fair digestion, and although it dropped to a pH of 6.6 to 6.8 for a short time, recovered to 7.0 or above and maintained itself there till placed on drying beds. Pit No. 1 dropped to 6.0. Temperature in both pits averaged 65° Fahrenheit throughout the experiments.

In order to promote alkaline fermentation in Pit No. 1, milk of lime was added. Over-enthusiasm on the part of the operators in adding the lime raised the pH so high as to effectually discourage the remaining bacteria for a time and the contents of the pit turned brown and lay dormant for about two weeks before digestion again commenced. During this period the odors, although abated to some extent, continued to be highly objectionable.

Pit No. 1, with 40 per cent seed, was interesting in disclosing that the proportion of seed to raw material was low. Pit No. 2 progressed to fair digestion in about forty-five days and although the contents could not be termed ripe in that time, they proved to be in such shape that when discharged into an adjacent sand bed, together with digested sludge from the main digesters, they dried without attendant odor or nuisance.

Pit No. 1 (40 per cent seed) has never been emptied but at the present time (May, 1932) has reached good alkaline digestion and, its capacity having been increased by erecting a dike around it at the ground surface, it is now receiving daily doses of about 25 cubic feet of bar screenings. There is still some odor but it is slight and is diminishing daily.

Pit No. 2 was partially emptied after about forty-five days of digestion (at which time it had developed a stratum of fairly clear, inodorous supernatant liquid) and refilled with bar screenings and skimmings. It is now progressing to digestion at a good rate, with no further addition of raw material and already, at the expiration of thirty days, shows decided evidence of again stratifying and producing good supernatant liquid. Both pits have to be agitated to keep the scum saturated.

As stated, Pit No. 1 receives a daily addition of 20 to 25 cubic feet of bar screenings and its condition meanwhile is steadily improving. It is giving increasing evidence of the ability of a digesting mass of sludge to do the job of destroying the putrefactive material caught up with bar screen-

ings. Already there is fair evidence that once this putrefying material is "washed out," the remainder can be dried without nuisance, even though much of it still retains its identity. It is thought that with properly constructed tanks, in which the temperature is maintained at approximately 85° F., this method of treating bar screenings will be greatly accelerated, and as soon as the convenience can be installed the experiment will proceed along these lines.

As a secondary issue, the material from such digestion is worth to the Districts $2.00 per dry ton delivered onto sand beds. Assuming that 15 per cent of the bar screenings is destroyed in the digestion process, there remains a gross return to the Districts of about $7.50 per year for each million gallons daily of sewage treated, significant only in the fact that capitalized it will provide for an investment of $112.50 per million gallons daily flow for handling bar screenings in this manner, an amount about sufficient to erect such simple tanks as are required for this purpose. Burning or burying would increase the cost of handling without a return on the investment.

In designing such tanks, the capacity requirements to be taken into consideration should permit digestion for a period of not less than sixty days in the presence of 50 per cent of good seed. It is also well to note that ordinary pumping facilities are inadequate for either stirring the material or transporting it to, or from, the tanks. Sticks and rags, which are still sticks and rags after digestion, cannot be readily pumped by equipment with moving parts, and the opinion of those who have been interested in this investigation is that nothing short of air lifts or ejector equipment will answer the purpose. For stirring sludge, and such procedure is necessary owing to the large accumulation of scum at the tank surface, a rather high capacity air or gas lift is required, one which will elevate material from the bottom of the tank and throw it out laterally over the top of the scum, acting as a scum saturator. For ejecting the material from the pits to the beds, an air lift will probably prove efficient. Transportation from the bar screens to the digesting pits can probably be best accomplished manually, excepting in very large installations where belt conveyors might be economical.

pH and odor can be controlled by proper seeding, provided an available supply of digested sludge is at hand, and should the digested mass retain some of its obnoxious odors at the time it is discharged to the beds, such odors can be effectively dampened by mixing the digested bar screenings with other well digested sludge on the beds.

Instead of calling the process the "digestion of bar screenings" it would be well to call it "the treatment of bar screenings with digested sludge," because, although after the period of digestion the bar screenings have lost their putrefactive elements, the larger and coarser particles and those which are not broken down will still retain their identity and will be readily distinguishable, though they may be dried and disposed of without nuisance.

Certain Environmental Conditions Affecting the Value of Thermophilic Seed Sludge*

BY H. HEUKELEKIAN

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The different factors affecting the value of ripe sludge for low temperature digestion have already been reported.[1] Factors such as stage of digestion and the period of storage of the seed sludge were found to have an important influence on digestion time. Similar questions arise in connection with thermophilic sludge. At what stage of decomposition is the sludge best suited for seeding? How long can seed sludge be stored without deteriorating? If it should be necessary to store thermophilic sludge without any additions of fresh solids, what is the best temperature for storage? In the absence of food, do the thermophilic organisms disappear more rapidly at high temperatures than at low temperatures? Can a low temperature ripe sludge be converted to thermophilic sludge by merely increasing the temperature of storage without any addition of food? We know that low temperature sludge is of considerable value in starting thermophilic digestion when mixed with fresh solids.[2] Can the same result be accomplished by incubating the low temperature sludge at 50° C. prior to the addition of fresh solids?

Method

To determine the effect of the stage of digestion of seed sludge on the digestion time, large quantities of fresh solids and thermophilic sludge were mixed 2:1 on the basis of volatile matter. A portion of the mixture was used to determine the rate of gas evolution in the original sample. Portions of this parent mixture were taken out at intervals and used to seed fresh solids on the original volatile matter basis. The original mixture as well as the subsequent mixtures were incubated at 50° C. After 28 days the original stock mixture, which was completely digested, was divided into two portions, one incubated at 20° C. and the other at 50° C. Again, at intervals, mixtures were made from the initial portion and stored at 20° C. and 50° C.

To determine the seeding value of low temperature ripe sludge for thermophilic digestion when stored at 50° C. a quantity of separate digestion sludge was incubated at 50° C. At intervals a portion of it was withdrawn, fresh solids added at the rate of 2:1 on the basis of volatile matter and the mixture incubated at 50° C. until digestion was complete, as indicated by gas measurements.

* *Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Dept. Sewage Research.*

Results

Stage of Digestion and Seed Value.—The effect of the stage of digestion of the seed sludge on subsequent digestion is given in Figure 1. It will be observed that the parent sludge attained the peak of gasification in 8 days and completely digested in 20 to 22 days. When the initial undigested sludge was used as seed the digestion in the new mixture was retarded considerably, owing to the dilution of the seed material. The lag period lasted 14 days and gasification was spread over a period of 30 days,

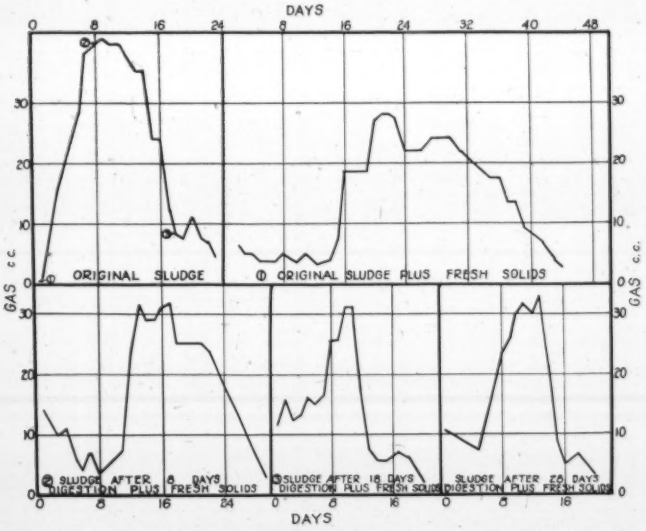
DAYS
GAS c.c.
① ORIGINAL SLUDGE
① ORIGINAL SLUDGE PLUS FRESH SOLIDS
② SLUDGE AFTER 8 DAYS DIGESTION PLUS FRESH SOLIDS
③ SLUDGE AFTER 18 DAYS DIGESTION PLUS FRESH SOLIDS
SLUDGE AFTER 20 DAYS DIGESTION PLUS FRESH SOLIDS
DAYS

FIG. 1.—The Effect of the Stage of Digestion of Seed Sludge on the Rate of Gasification in Thermophilic Digestion (Gas per Gram Solids).

giving a total period for complete digestion of 44 days. When the sludge at the peak of gasification was used as seed, the entire period for complete digestion was reduced to 30 days. The sludge used for seeding when the rate of gasification had just diminished (18 days) digested in 14 days. Further incubation of seed sludge thereafter did not materially affect the value of the sludge as seed. These results are presented in Table I which gives, in addition, the ash content of the seed sludge at the various periods. The degree of digestion of the seed sludge, as calculated from the percentage

TABLE I

STAGE OF DIGESTION OF SEED SLUDGE AND ITS EFFECT ON DIGESTION TIME

Days Digestion in Progress When Sludge Was Used as Seed	Per Cent of Total Gas Produced	Per Cent Ash in Sludge	Days Required for Digestion
3	0	26.9	43
8	43	28.2	29
18	93	37.2	14
28	100	39.3	16

of the total gas produced at the various periods when the sludge was used as seed, showed, when plotted against the efficiency of the sludge as seed material as determined from the days for complete digestion, a linear rate. (Figure 2.) In other words, the value of sludge as seed increases directly up to a certain point as digestion proceeds. When digestion is completed

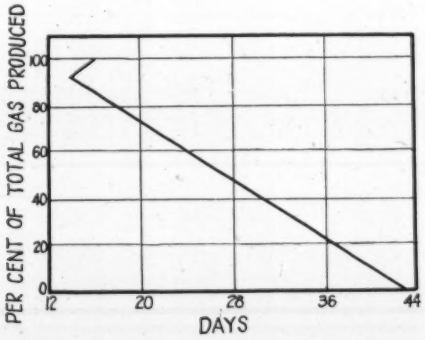

FIG. 2.—Comparison of Degree of Digestion of Seed Sludge as Measured by Per Cent of Total Gas Produced, with the Days Required for Complete Digestion.

this relationship does not hold and there is no further benefit to be derived from additional incubation. The sludge is in its most valuable stage as seed when 90 to 95 per cent of its gas has been produced.

Time and Temperature of Storage.—The effects of the time and temperature of storage of ripe thermophilic sludge on its seeding value are presented in Figure 3 and Table II. The original sludge mixture was divided into two portions at the end of 28 days of digestion; one part was stored at 50° C. and the other at 20° C. At intervals these two sludges were used to make new mixtures for digestion at 50° C. and the time required for digestion determined. The day when the original sludge mixture was thus divided was taken as the initial point of storage for this part of the experiment, although the sludge was completely digested 10 days

TABLE II

EFFECT OF TIME AND TEMPERATURE OF STORAGE OF SEED SLUDGE ON DIGESTION TIME

Days Storage	Temp. Storage, ° C.	Ash, %	Days Required for Digestion
14	50	31.2	17
14	20	33.0	17
38	50	40.1	19
38	20	40.3	19
76	50	41.2	18
76	20	40.0	17

prior to this. The results show that storage of sludge after the digestion is completed, up to 76 days at 50° C., did not materially increase the time of digestion. Storing the sludge at 20° C. did not affect the results one way or the other.

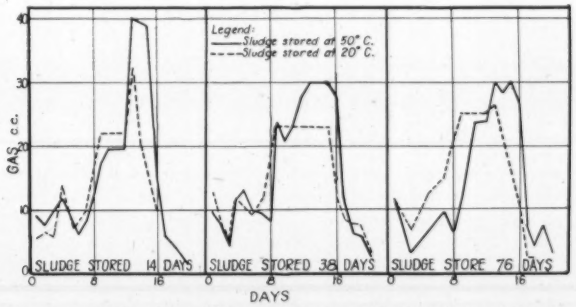

FIG. 3.—The After-Effect of Storage of Thermophilic Seed Sludge at 50° and 20° C. on Digestion (Gas per Gram of Solids).

Thus thermophilic sludge can be maintained without food for periods of 2 to 3 months. In order to conserve heat supply during such periods, the temperature of storage can be lowered to about 20° C. without any deleterious effects. What would happen with storage periods beyond 3 months is not known, but it is interesting to note that in the case of low temperature ripe sludge, the deleterious effects of storage were not noticeable until after 3 months of storage.

Changing Low Temperature Sludge to Thermophilic Sludge.—The ripe separate-digestion sludge when incubated at 50° C. produced only small quantities of gas. The original sludge had an ash content of 41 per cent, which on incubation at 50° C. for a period of 100 days increased to 46 per cent (Table III). Nearly 20 per cent reduction of volatile matter took place in this period. This would indicate, as has been shown pre-

viously, that the digestion under thermophilic conditions is somewhat more complete.

The results obtained by the use of this sludge as seed after different periods of incubation at 50° C. are presented in Figure 4 and Table III. The initial sludge, without any prior incubation at 50° C., when mixed

TABLE III

EFFECT OF INCUBATION OF RIPE SLUDGE AT 50° C. ON THERMOPHILIC DIGESTION

Incubation 50° C., Days	Solids	Per Cent Ash (Dry Basis)	Reduction	Digestion Completed, Days
0	4.41	41	..	37
8	4.05	43	11.1	35
18	4.02	43.6	13.1	26
28	3.95	44.5	14.1	28
42	3.50	44.0	24	20
65	3.77	46.1	21.9	22
105	3.90	45.5	18.5	22

with fresh solids and digested at 50° C., completed its digestion in 37 days. After 8 days incubation at 50° C. the digestion period was 35 days. The digestion period was decreased to 20 days when the sludge was incubated for 42 days prior to mixing. Thereafter no further reduction in digestion time took place.

Thus it is possible to subject ordinary ripe sludge to the thermophilic range of temperature prior to the addition of solids and obtain a considerable increase in its efficiency as seed. The time required for complete digestion at 50° C. was reduced from 37 days, when a low temperature sludge was used as seed, to 20 days when the same sludge was stored for 40 days prior to mixing. Thus the total time, including the storage and digestion periods, is nearly 60 days. However, when a low temperature sludge mixture was digested at 50° C. without any prior storage the digestion time was only 37 days. Thus there is no advantage in storing the low temperature sludge at 50° C. prior to making the fresh solids addition.

Conclusions

An attempt to determine the effect of certain factors on the seeding value of thermophilic sludge revealed the following:

1. The degree of digestion of the seed sludge affected materially the digestion time of the mixtures made from it.
2. Sludge as seed is best used when 90 to 95 per cent of the total gas has been produced.
3. Storage of thermophilic sludge up to 3 months did not cause deterioration in its seeding value.
4. From the standpoint of seeding value it made little difference whether the sludge was stored at 50° C. or at 20° C.

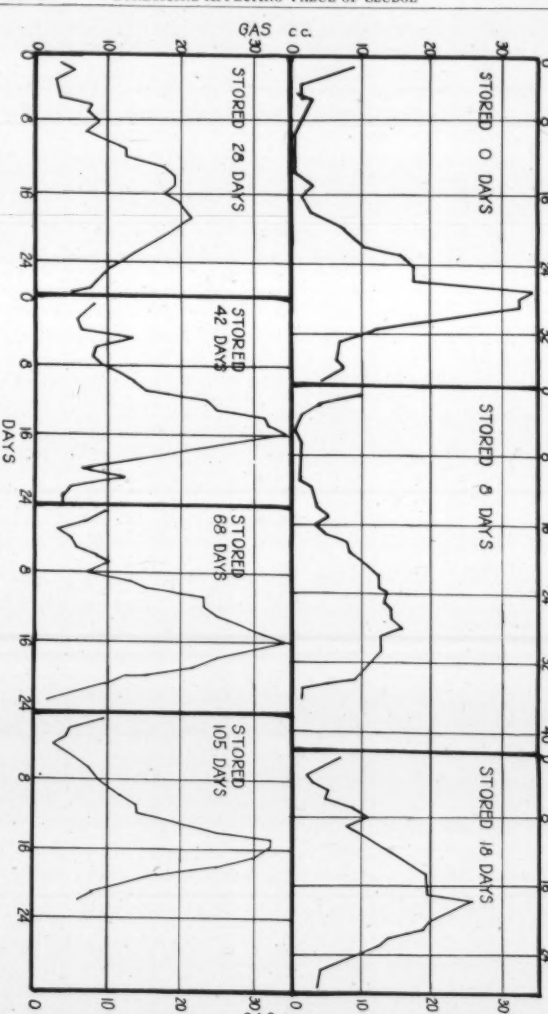

FIG. 4.—Effect of Incubation of Low Temperature Sludge at 50° C. for Various Periods Prior to Its Use as Seed in Thermophilic Digestion (Gas per Gram Solids).

5. Storage of low temperature sludge at 50° C. increased its seeding value for thermophilic digestion.

6. Storing low temperature sludge for 40 days at 50° C. decreased the time required to complete the digestion of fresh solids at 50° C. from 37 to 20 days.

7. Digestion time was longer with the batch process than with the continuous process (daily additions).

References

[1] H. Heukelekian, "Studies on the Function of Ripe Sludge," THIS JOURNAL, **2**, 313–37 (1930).

[2] W. Rudolfs and H. Heukelekian, "Thermophilic Digestion of Sewage Solids," *Ind. Eng. Chem.*, **22**, 96 (1930).

The Thermophilic Digestion of Municipal Garbage and Sewage Sludge, with Analogies*

BY CHARLES GILMAN HYDE

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Introduction.—The process of hastened digestion of manure, garbage and other similar organic products through the activities of that group of organisms known as the thermophilic or heat-loving bacteria was first conceived and developed by Dr. Giuseppe Beccari at Florence, Italy, nearly if not quite 20 years ago. The earliest experiments with thermophilic digestion of sewage sludge, of which the writer is aware, were those undertaken at the New Jersey Agricultural Experiment Station, Department of Sewage Disposal, by Dr. Willem Rudolfs and Dr. H. Heukelekian in the winter of 1927–28.

The numbers of papers published in the United States dealing with the thermophilic digestion of garbage and of sludge are perhaps about the same, but the discussions of the latter procedure are far more technical, voluminous and exhaustive. Less than ten papers referring to the Beccari process of garbage treatment, embracing not more than 20 pages, have been published to date in the United States. All of these articles have been merely descriptive or popular and quite superficial and untechnical.

Under the circumstances it would seem to be desirable first to describe each of the processes in question and then to note the features which are similar and which may possibly aid in interpreting the procedure of developing thermophilic activity as a general method of digestion of organic matter.

Definitions and Brief Description of Raw Material

Garbage.—Municipal garbage, in the correct use of the term, comprehends the waste animal and vegetable matters from domestic, restaurant and hotel kitchens and from meat, vegetable and fruit markets, together with certain abattoir and packinghouse wastes. It consists almost wholly of organic matter and water. It is subject to rapid decomposition through bacterial action if the temperature is sufficiently high (55° F. or above) to foster the growth of such organisms. Garbage normally forms a fairly compact, dense mass which cannot absorb oxygen readily. It is therefore subject to putrefactive (anaerobic) decomposition, giving rise to obnoxious odors.

From the strictly hygienic standpoint, garbage is significant mainly

* *Presented before the Fourth Spring Conference, California Sewage Works Association, Yosemite National Park, California, May 21, 1932.*

because it furnishes food for rats and constitutes a nearly perfect breeding place for flies.

The volume and weight of garbage and its composition are of course closely related to the character of the contributing population. These factors vary, therefore, with variations in the utilized food supplies, and the general thriftiness of the group from which the garbage is derived. They also vary as between climatic zones and climatic conditions in general.

The composition of garbage as collected from certain of the larger cities in the United States is indicated by the figures in Table I.

TABLE I

COMPOSITION OF GARBAGE FROM CERTAIN LARGER CITIES IN THE UNITED STATES[1]

Constituent or Factor		General Average	Average Maximum*	Average Minimum*
Nitrogen	% by Weight	1.06	3.05	0.35
Phosphoric Acid	% by Weight	0.90	3.81	0.19
Potash	% by Weight	0.54	1.22	0.20
Grease	% by Weight	3.55	5.49	1.71
Moisture	% by Weight	75.5	80.6	71.4
Combustible	% by Weight	20.6	23.4	16.8
Non-combustible	% by Weight	3.6	5.2	2.6
Volatile	% by Weight	19.9	22.7	16.9
Fixed Carbon	% by Weight	4.1	4.7	3.7
Ash	% by Weight	5.4	7.7	3.6
B. t. u. per Lb.		8300.0		
Pounds per Cap. per Year		180.0	320.0	60.0
Cubic Feet per Cap. per Year		5.36	8.98	1.82
Pounds per Cubic Yard		1053.0	1500.0**	660.0**

* The absolute maximum and minimum values for short periods are probably much greater and less, respectively, than the figures here given.

** Probable maximum and minimum values for small quantities.

The variation in the production of garbage as between the months of the year is well illustrated by statistics showing the weight of garbage contributed by 10 cities in the United States. In these the average annual production was 620 pounds per day per 1000 population. The average monthly weight produced by the entire group was 840 pounds in September and 460 pounds in February. These figures are, respectively, 136 and 74 per cent of the average annual contribution. The weight for September was 183 per cent of the February weight.[1]

Sludge.—Sewage sludge may be defined as the material removed from raw or treated sewage by subsidence. Raw sludge and activated sludge, together with certain other types of sludge, such as that produced by chemical precipitation, are unstable or putrescible and unless treated further, as by digestion and dewatering, will almost inevitably cause difficulty and nuisance in disposal. It is not to be questioned that diges-

tion at the present moment may be considered to be the cheapest, most logical and most available method of treating sludge to the point where its disposal, other than by dilution in adequate volumes of water, becomes a satisfactory procedure.

The solids deposited from sewage, termed sludge, retain relatively great volumes of water in a most tenacious manner. The energy required to dissociate the absorbed or contained (bound) water is very great. While purely physical means of such dissociation are possible, they are to be regarded generally as economically infeasible. Within recent years it has become to be realized that this reduction of water content, with attendant physical-chemical changes in the composition of the sludge, can perhaps best be accomplished by the anaerobic bacteria. It has further become appreciated that plain subsidence is a valuable, indeed almost neces-

TABLE II

ROUGH GENERAL AVERAGE COMPOSITION OF RAW, ACTIVATED AND DIGESTED SLUDGES AS PRODUCED AT CERTAIN SEWAGE TREATMENT PLANTS IN THE UNITED STATES[2]

Constituent or Factor		Raw Sludge	Activated Sludge	Digested Sludge
Volatile Matter	% Dry Weight	73.0	64.3	50.0
Ether Soluble Matter	% Dry Weight	7.5±	5.8	6.2
Nitrogen, Total	% Dry Weight	3.0±	4.9	2.0
Phosphates, as P_2O_5	% Dry Weight	2.8±	2.3	1.4
Potassium, as K_2O	% Dry Weight	0.6±	0.5	0.6
Ash	% Dry Weight	30.0±	45.0	45.0±
pH Value		5.6	5.8	7.1
Water Content	Per Cent	95.0	98.0	91.5
Specific Gravity		1.020	1.005	1.035
Dry Solids, Lb. per Mil. Gal. of Sewage		1080.0	2,250.0	690.0
Dry Solids, Lb. per 1000 Population Daily		108.0	225.0	69.0
Gal. per Mil. Gal. of Sewage		2500.0	13,500.0	500.0
Cu. Ft. per 1000 Population Daily		33.0	181.0	6.7

sary, process preparatory or preliminary to any subsequent economical final treatment aimed at the production of a stable effluent.

As a practical matter the two types of sludges for which digestion is to be considered at the present time a most logical procedure are: (1) raw sludge; (2) activated sludge.

The weight and volume and the composition of sludge are related to the characteristics of the sewage from which it results, and these in turn depend upon the character of the population, particularly as respects its industrial development, from which the sewage is contributed.

The general composition of raw, activated and digested sludge is indicated approximately by the figures in Table II.

Purpose of Thermophilic Digestion of Garbage and Sludge.—The fundamental purpose of thermophilic digestion of garbage is the produc-

tion of a stable, fairly dry (10 to 12% moisture), innocuous humus in a relatively brief period of time from wet, putrescible, nuisance-provoking garbage or other similar organic wastes. The Beccari process of thermophilic digestion is capable of accomplishing this result in from 30 to 40 days with mean digestion temperatures for the period ranging around 130° F.

Similarly, by thermophilic digestion of sewage sludge it is proposed to reduce greatly the period required to render raw, activated and perhaps other sludges (which, until digested or otherwise treated, are unstable and drainable only with great difficulty) stable and dewaterable. Thermophilic digestion of sludge is capable of greatly reducing the time required for reasonably complete digestion. By its use the digestion period may be positively lowered to 10 to 12 days, as compared with, say, 30 days for digestion conducted at 82° F., or possibly 20 days for digestion conducted at 92° F. In laboratory experiments, under controlled conditions, thoroughly ripe sludge has been produced in from 24 to 48 hours.

The Thermophilic Organisms.[3,4]—Bacteria of the thermophilic group have been known and recognized for many years. In 1875 Cohn isolated a facultative thermophile, *Beggiatoa nivea Rabenhorst*, from the sulphur springs at Aargau, Switzerland. A strictly thermophilic bacterium was first isolated in 1879 by Miquel from the river Seine. Miquel (1881, 1882, 1888) was also the first to isolate thermophilic bacteria from soil and feces. Many other investigators have isolated spore-forming thermophiles from rivers, canals and hot springs; from feces, sewage and manure; from soil; from milk and canned goods; and from silage and various fermenting organic substances. Certes and Garrigou in 1886 and Winogradsky in 1887 isolated thermophiles from rivers, canals and hot springs. In 1884 Dehérain isolated organisms of this group from feces or sewage and manure. In 1888 Globig isolated thermophilic organisms from soil. Bardou in 1906 reported the isolation from sewage of 4 strains of facultative anaerobes which grew equally well at 64° F. and 140° F.

Robertson, reviewing the literature to the year 1927, found 408 papers, by 327 authors and 78 co-authors, relating wholly or in part to the thermophilic bacteria. Since that time much further work has been done upon this group of organisms, especially in their relation to food preservation and the canning industry. The thermophilic bacteria, as a class, present many investigative difficulties and baffling problems. Despite the large amount of laboratory study which has been put upon them, relatively little is yet known concerning them. This is notably true in respect to the thermogenic (heat-producing) strains. It is also generally true as related to the economic control and utilization of the thermophilic group.

The thermophilic or heat-loving bacteria are those which thrive at temperatures well above the maxima tolerated by the great majority of

bacteria, particularly the pathogenic forms. True thermophiles show no growth, or only feeble growth, below 104–113° F. However, certain facultative thermophilic bacteria have been discovered, as indicated above, which develop at room temperature or about 68° F., and have their optimum temperature at about 122° F. and their maximum at 140° F. True thermophiles grow best between 130° and 170° F.

There are two distinct types of thermophilic bacteria: the spore-forming and the non-spore-forming. The former greatly predominate. In fact, up to 1927, only one non-spore-forming thermophile had been isolated. Milk was the only recognized source of this species in 1927.

Aerobes, facultative anaerobes and strict anaerobes are all to be found among the spore-forming thermophiles.

The fact that certain thermophilic bacteria are spore formers is doubtless of great importance in the conduct of garbage digestion in Beccari cells. The reason for this belief lies in the fact that the cells are opened and emptied of their contents at 35 to 40 day intervals. When open and exposed to the air, the masonry cell walls become relatively cold and lose much if not nearly all of their adherent moisture. When again filled with garbage and tightly closed, the bacteria seem to develop throughout the mass with great rapidity in enormous numbers. This growth must take place from the walls and racks, to be later described, inward through the mass of garbage.

Many of the thermophilic bacteria are also thermogenic. Since no external source of heat is utilized in the Beccari cells, it is to be presumed that the high temperature produced is due in large part to the activity of the thermogenic forms of thermophiles. It is possible, also, that some of the heat developed in the garbage masses in Beccari cells is due to hydrolysis.[5]

All organisms liberate more or less energy in the form of heat as the result of their processes of growth. Sierp[6] has shown that a large amount of heat is generated by biological processes in sludge undergoing digestion. Such digestion is purely anaerobic. While it is possible that fresh garbage may contain a significant amount of free oxygen, it is certain that this supply becomes quickly exhausted in an air-tight Beccari cell and that thereafter the development of thermogenic thermophiles must be among the anaerobic or facultative anaerobic strains.

If anaerobic or facultative anaerobic strains of thermogenic thermophiles could be developed in sewage sludge undergoing digestion, it is possible that the amount of heat developed would be so large that it would be unnecessary to utilize external sources of heat to the extent which the current experimental evidence seems to indicate.

The Thermophilic Digestion of Garbage by the Beccari Process.—The Beccari process of garbage treatment has been in practical use for

18 years. The process was first developed in Italy and has been gradually extended to various countries in Europe and in South America, and to the United States. There are perhaps 80 municipal plants now in use or under construction in various parts of the world. To date, however, only 5 small plants have been built in this country.

The process is typically conducted in simple cubical cells of masonry which ordinarily are built to receive from 18,000 to 25,000 pounds of raw garbage, this weight depending upon the moisture content of the material and the effective height of the cell. The cells are loaded solidly from slatted platforms placed several inches above the cell floors to the tops or roofs, except that slatted racks with end supports are introduced to limit each layer of garbage to 20 inches in depth. There may be several such layers of garbage. The usual number is 3, but 4 or even 5 can doubtless be employed equally well. Each cell has a top loading hatch and a side unloading door, together with vent openings just above the floor and just below the roof. The floor of each cell is sloped and provided with a drain. During the process of digestion the mass of garbage shrinks greatly and the several layers of drying material are retained upon their respective racks.

As soon as a cell is filled, it is sealed tightly. The temperature soon begins to rise and in from 5 to 7 days a maximum of 140–160° F. is attained. The top and bottom vents are opened after 7 or 8 days. The high temperature is maintained for 4 or 5 days, or until perhaps the tenth day after closing the cell. Thereafter the temperature falls slowly to perhaps 100° F. at the time that the cell is opened for unloading. The average temperature for the period is perhaps 130° F. The normal digestion period is 35 days. The program just recited is a typical one. As in all biological processes there are some variations caused by such factors as the outside and interior temperatures, the character of the garbage, etc.

During the period of digestion the thermophilic bacteria develop rapidly in enormous numbers. Studies conducted at Florence indicate that the thermophiles may develop in 10 days to the number of 100 million per gram and that subsequently this number is maintained until the cell is opened for unloading. Complementary micro-flora, present originally in perhaps even greater numbers, are largely destroyed or overwhelmed and fall to perhaps one million per gram in about 7 days, after which this approximate number is maintained throughout the digestion period. All known forms of pathogenic bacteria are quickly destroyed. The flesh of animals and fish is entirely consumed within the usual operating cycle of 35 days.

The raw putrescible garbage, generally containing from 70 to 80% moisture, and possibly averaging 75%, is reduced to a stable, odorless

humus normally containing from 10 to 15% of moisture. The weight of humus recovered amounts to from 10 to 20% of the raw garbage introduced into the cells. The loss of weight is accounted for by the reduction in the moisture content and in the production of gas. It is probable that in the early stages of digestion some of the organic matter is hydrolyzed. The produced humus constitutes a valuable fertilizer.

Unfortunately there appears to be no available information relative to the amounts and kinds of gas produced by the digestion or to the character of the liquid drained from the cells.

The Thermophilic Digestion of Sewage Sludge.—Thermophilic digestion is applicable to all types of undigested sewage sludge, notably raw sludge resulting from plain subsidence and activated sludge. The process is conducted in closed tanks which in current practice, and in the absence of specific anaerobic thermogens, must be heated to the optimum temperature somewhere between 120° and 140° F. Thermophilic digestion is still in the experimental stage. It has been demonstrated to accomplish in a few days the same results as are achieved in much longer periods by digestion with other and more usual types of anaerobes at lower temperatures

In the process of digestion of sewage sludge approximately one-third of the original weight of solid matter is transformed into gas (methane, carbon dioxide, hydrogen, ammonia, etc.), one-third is converted into water and one-third remains as humus.

As in other anaerobic processes of digestion the best results are secured with alkaline conditions in the tanks: *i. e.*, with pH values above 7.0.

The humus resulting from the process, when dried, is stable and practically odorless. It constitutes a valuable fertilizer.

Analogies Between Thermophilic Digestion of Garbage and Sludge.—There are many interesting analogies between the thermophilic digestion of municipal garbage as conducted in the Beccari cell and the thermophilic digestion of sewage sludge as developed to date by laboratory and field experimentation.

One striking difference should be noted, however. The digestion of garbage is as yet only a batch process, while that of sludge is ordinarily a continuous procedure. It is simpler and cheaper to operate the former as a batch process and to operate the latter as a continuous process.

Some of the more apparent analogies with respect to these two processes in question may be mentioned.

Seeding.—Experience indicates that three or more cycles of operation are necessary with new Beccari cells before satisfactory digestion is established, unless seed material in the form of humus from a properly operating cell is introduced with the raw garbage. If such seeding is had, good results seem to be obtained at once.

In exactly the same way it is necessary to develop satisfactory seed sludge in order to conduct thermophilic digestion of sewage sludge. Dr. Rudolfs and Dr. Heukelekian[7] have demonstrated that not only the type of seed sludge must be suitable but that the amount must be sufficient and must be related to the amount of raw sludge introduced into the digestion tank.

Temperature.—The temperature developed and maintained in Beccari cells treating garbage is that apparently necessary for the functioning of the thermophilic group of bacteria. The maximum temperatures attained vary from perhaps 140° to 160° F. while the mean or average temperature for the digestion cycle may be about 130° F.

Similarly, to obtain optimum results in the digestion of sludge, it is necessary to generate and maintain a temperature of 120° to 140° F., the average best temperature being possibly 130° F., or perhaps slightly less.

pH Value.—The optimum pH value of garbage undergoing digestion in Beccari cells is not known. Experience has shown, however, that garbage containing large quantities of citrus wastes, for example, is more rapidly and more satisfactorily digested if hydrated lime is added to the garbage during the process of loading the cells. This is particularly true of new cells. In some plants, lime is added as a routine procedure. In one plant a small amount of ammonium sulphate in the form of a dry powder is added to each batch of garbage placed in the cells. This is believed to be efficacious in stimulating anaerobic action.

The optimum pH value of sewage sludge undergoing digestion at whatever temperature is also on the alkaline side: *i. e.*, 7.0 or over. If this cannot otherwise be secured, liming becomes necessary. However, in well seeded tanks, lime is generally unnecessary as is also the case in well operating Beccari cells under normal conditions and with normal garbage.

In developing the thermophilic process of sludge digestion, in the absence of proper seed sludge, Dr. Rudolfs and Dr. Heukelekian[8] have shown that the addition of lime and of three alkaline salts, namely, ammonium bicarbonate, ammonium carbonate and di-potassium phosphate, accomplished much the same results as were secured with proper amounts of the well digested sludge itself.

Reduction of Moisture Content.—If a cubic yard of garbage weighing 1050 pounds and containing 75% of moisture is reduced to 15% of humus with a 12% moisture content, the loss of water in the process amounts to 769 pounds.

Similarly, if a cubic yard of raw sewage sludge containing 95% of moisture and having a specific gravity of 1.02, and therefore weighing 1717 pounds, is reduced to a digested sludge containing 91% of moisture, the loss of water in the process amounts to 761 pounds.

There is probably no special significance to be attached to these closely comparative figures. They serve principally to attest to the large volume of water removed in each process from the raw material introduced.

Character of Humus Produced.—The humus produced in a Beccari cell, at the end of a normal 35-day period, during the last 27 or 28 days of which the vents have been open, has the following general composition, based on dry weight:

Nitrogen	= 2.5%
Phosphates, as P_2O_5	= 2.9%
Potassium, as K_2O	= 1.2%

The humus resulting from sludge digestion has the following general composition, based on dry weight, in respect to the constituents named above:

Nitrogen	= 2.1%
Phosphates, as P_2O_5	= 1.4%
Potassium, as K_2O	= 0.6%

References

[1] Hering and Greeley, "Collection and Disposal of Municipal Refuse," McGraw-Hill Book Company.

[2] (*a*) Metcalf and Eddy, "Sewerage and Sewage Disposal," McGraw-Hill Book Company; (*b*) Report of Committee on Sludge Digestion, Sanitary Engineering Division, American Society of Civil Engineers, *Civil Engineering*, **2**, 169–72 (March, 1932).

[3] A. H. Robertson, "Thermophilic and Thermoduric Micro-organisms, with Special Reference to Species Isolated from Milk—I, Review of Literature," N. Y. State Agricultural Experiment Station, *Technical Bulletin*, No. 130.

[4] S. R. Damon and W. A. Feirer, "Anaerobic Sporulating Thermophiles," *Journal of Bacteriology*, **1924**, pp. 37–46.

[5] Stanley Thomas, "Bacteriology," McGraw-Hill Book Company.

[6] Dr. F. Sierp, "Specific Heat, Conduction and Generation of Heat During the Digestion of Sewage Sludge," THIS JOURNAL, **2**, 191–8 (April, 1930).

[7] (*a*) W. Rudolfs and H. Heukelekian, "Thermophilic Digestion of Sewage Solids," *Ind. Eng. Chem.*, **22**, 96 (January, 1930); (*b*) H. Heukelekian, "Thermophilic Digestion of Daily Charges of Fresh Solids and Activated Sludge," THIS JOURNAL, **3**, 3–23 (January, 1931).

[8] H. Heukelekian, "Further Studies on Thermophilic Digestion of Sewage Solids," THIS JOURNAL, **2**, 219–27 (April, 1930).

Nitrogen Fixation in Activated Sludge

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The fixation of atmospheric nitrogen during the activated-sludge process, a subject of manifest interest and importance, has been a controversial matter. It is not within the scope of this paper to review the literature on that subject. For such discussions the reader is referred to those of Buswell (1923, 1928). One of the latest claims for the actuality of the phenomenon has been made by Peck (1923) with the suggestion that organisms of the crenothrix group are responsible for the fixation.

The present studies were developed as ramifications of other work on the applications of activated-sludge treatment to dairy wastes, and, since the set-up utilized in those studies seemed well adapted to a study of nitrogen changes, the question of fixation was investigated.

The aeration chamber was a galvanized cylindrical tank 15 inches in diameter and 21 inches high, tapering from a point 5 inches above the bottom to a diameter of 5 inches at the bottom. A well, 4 inches in diameter and 17 inches in height was attached to the floor of the tank, and the upper end by vanes to the sides of the tank. Ports were cut in the sides of the well at the lower end. A shaft having a propeller mounted in the well supplied the aeration when the tank was filled to the level of the wall by forcing the liquid through the lower ports, raising the level outside so that it streamed down into the well. The shaft was driven by a $^1/_8$-h.p. motor. Sludge was withdrawn through a $^3/_4$-inch pipe at the bottom.

The first studies were made with an activated sludge built up from a 2 per cent milk waste, made by mixing skim milk powder with tap water. The sludge thus developed gave a very satisfactory effluent. The advantage of this particular type of waste lay in its constant composition. A number of preliminary runs, with an aeration period of 21 to 24 hours, on which nitrogen determinations* were made at frequent intervals, revealed in general a net loss of nitrogen at the end of the period. Typical results are shown in Table I.

The data show some incongruities. There are at times apparent rises in the N content, and on one or two occasions a net increase was indicated. Refinements in sampling technique and in the set-up reduced or eliminated much of the inconstancy.

Loss of ammonia was known to occur at times, and as there was also the possibility of other volatile nitrogenous substances being formed and es-

* Nitrogen, including nitrates, was determined by the Gunning-Arnold modification of the Kjeldahl method.

TABLE I

MILLIGRAMS OF N PER 100 CC. AT INTERVALS DURING AERATION

Run	Sampling Interval 0	2–4	10–12	15–17	Hours from Start 21	24–25	45
1	27.5	25.8	25.0	24.6	23.5	..	..
2	25.1	..	23.8	23.5	23.5	23.4	..
3	29.0	31.1	31.4	31.2	29.8	28.3	..
4	30.3	29.7	30.4	28.0	30.7	27.0	..
5	26.2	22.7	..	..	..	24.0	..
6	..	..	28.3	32.1	30.8	30.7	28.4

caping, the apparatus was modified by sealing the tank with a tightly fitted lid. The propeller shaft pierced the lid through a mercury seal. Holes cut in opposite sides of the tank were stoppered with one-hole rubber stoppers fitted with glass elbow tubes. Air, passed through a flask of sulphuric acid to eliminate the NH_3, was pulled into the tank by a suction pump, the evacuated air passing through a flask of sodium hydroxide and a second flask of sulphuric acid. At the end of a run the contents of these two flasks were mixed, left slightly acid, and returned to the tank to

TABLE II

NITROGEN BALANCE* DURING ACTIVATION OF DAIRY WASTE

Day	N in Seed Sludge, Mg.	Total Mg. N at Start of Run	Total Mg. N in Tank 22 Hours	Mg. N Loss	Gain
1	11,470	13,990	13,968	22	...
2	13,000	15,520	15,506	14	...
3	11,263	13,783	13,800	...	17
4	11,400	13,920	13,986	...	66
5	11,450	13,970	13,947	23	...
6	12,670	15,190	15,191	19	...
7	12,224	14,744	14,719	25	...
8	12,352	14,872	14,860	12	...
9	11,878	14,398	14,409	...	11
10	12,188	14,708	14,700	8	...
11	12,219	14,739	14,719	20	...
12	12,214	14,769	14,747	22	...
13	12,109	14,629	14,656	...	27
14	13,118	15,638	15,630	8	...
15	12,422	14,942	14,929	13	...
16	12,365	14,885	14,897	...	12
17	12,283	14,803	14,753	50	...
18	11,989	14,509	14,518	...	9
19	12,126	14,646	14,628	18	...
20	12,411	14,931	14,830	1	...
21	12,326	14,846	14,838	8	...
	Totals	=		263	142
	Loss	=		121	...
	Per cent loss	=		0.22	...

* Analytical results expressed as average of four samples.

be thoroughly mixed with the tank contents before the final sampling. A typical run under these conditions was as follows:

Nitrogen of tank at beginning, mg./100 Cc. = 31.4 (avg. of 3 samples)
Nitrogen of tank at end, mg./100 Cc. = 31.3 (avg. of 3 samples)

The experiment was continued with the daily addition of a constant amount of milk powder over a period of 21 days. No attempt to determine the various forms of nitrogen was made; total nitrogen at the beginning and end of each 22 hour period being the only consideration. Two hours sedimentation was followed by withdrawal of the supernatant and the addition of new material. The nitrogen balance over this period is shown in Table II.

The observable net loss of 0.22 per cent is of no significance since analytical and sampling error exceed this figure.

Efforts to induce the development of crenothrix in the sludge failed.

Domestic sewage free from trade wastes was studied under the same conditions. Ferric chloride equivalent to 10 p. p. m. was added to promote the growth of crenothrix and the tank was seeded with these organisms. At the end of 7 days they seemed well established. The experiment was carried on through a period of 21 days with the daily addition of fresh solids carefully sampled and accurately measured, as was the supernatant liquor after settling. No sludge was drawn during the period of the experiment. The data are shown below:

Total nitrogen added	32,773	mg.
Nitrogen accounted for in supernatant	10,187	mg.
Nitrogen accounted for in sludge	22,477	mg.
Total nitrogen accounted for	32,664	mg.
Loss	109	mg.
Per cent of loss	0.33	

The net loss of 0.33 per cent for the 21-day period means little and probably represents sampling or measuring error rather than real loss. The results are a practical confirmation of those secured by Buswell (1923). The slightly lower results are merely an expression of more accurately controlled conditions.

Summary and Conclusions

Nitrogen fixation by activated sludge has been studied in a small experimental plant, so constructed as to eliminate absorption of atmospheric ammonia, and to permit the recovery of volatile nitrogenous compounds.

Over a 21-day period an activated sludge built up from skim milk powder

showed no evidence of a nitrogen gain. Activated sludge seeded with crenothrix, utilizing domestic sewage, gave similar data.

Little evidence of denitrification to the point of formation of elementary nitrogen was observed.

From these data it would seem that fixation of atmospheric nitrogen by activated sludge, if occurring at all, must be an unusual phenomenon unlikely to occur in routine treatment.

References

A. M. Buswell, Illinois State Water Sur., *Bull.* **18** (1923).

A. M. Buswell, "Chemistry of Water and Sewage Treatment," Chemical Catalog Company, 1928.

C. L. Peck, *Eng. New Rec.*, **90**, 487 (1923).

Plant Operation

A Review of Sewer Rental Laws and Charges

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Editor's Note.—This digest of sewer rental laws and charges was prepared at the direction of the Metropolitan Drainage Commission of Minneapolis and St. Paul by Messrs. Childs and Schroepfer. The report was submitted as an impartial presentation of facts and opinions for the use of those interested in the possible application of sewer rental charges to the Minneapolis and St. Paul sewage disposal project, and it is the authors' intention that nothing in the report shall be construed as bias for or against the principles of sewer rentals. It is the most comprehensive report on this subject that has come to the attention of the Editor, and it is of particular interest just at present in connection with the passage of sewer rental laws in various states in order to place sewerage and sewage treatment projects on a "self-liquidating" basis. The information in the report ought to be of great practical value to the readers of This Journal.

I. Introductory

Sewerage systems in the United States in nearly all instances in the past have been financed through general tax levies and special assessments. Where there were no treatment works and the sewage would simply flow by gravity to the river to be disposed of by dilution, the operation and maintenance charges were relatively small, consequently this method of paying the cost was simple, and in most instances, satisfactory.

The rapid increase in the number of treatment works, with consequent higher operation and maintenance costs, has introduced a new factor in the matter of financing which is now receiving a great deal of attention. It is believed by many that the assessed valuation method of financing the costs of treatment is not a sufficiently accurate measure of each individual's share of the burden and that charges should be made which more nearly represent the cost of service rendered, as is the case with other public utilities such as gas, water and electricity.

Recently, and principally during the last ten years, a number of municipalities have applied what are known as "sewer rental charges," which are based either upon the quantity of water consumed, the number and type of plumbing fixtures, the number of persons served, the type of premises, the character of the sewage, or upon a combination of one or more of these methods. Interest in this type of charge for sewer service has been increasing rapidly in recent years, as evidenced by the number of municipalities now making such charges.

II. Status of Sewer Rental Laws in the United States

While marked interest has been shown recently in sewer rental laws, the principle of sewer rental charges dates back over forty years. In 1892 Massachusetts passed a law (General Laws, Chapter 83, Section 16) providing for the establishment of "just and equitable annual charges for the use of common sewers." In fact the application of charges for sewer maintenance dates back to 1796 when the Acts and Resolves of Massachusetts, Chapter 14, provided "that when any common sewer shall be stopped or gone to decay, the selectmen of the town shall assess the cost of the repairs upon those benefited by the sewer."[32] Brockton, Mass., passed a sewer rental ordinance in 1894 which has been in force continuously from that time. The state of Indiana is the latest to pass a sewer rental law (enacted August 17, 1932).

At the present time 26 states and the District of Columbia have either passed sewer rental laws or their constitutions are such that charges for sewer service can legally be made. The following tabulation lists the states and the number of known municipalities having local ordinances providing for service charges as of 1931.

State	Number of Municipalities Making Service Charges
(1) Alabama	2
(2) Arizona	1
(3) Arkansas	1
(4) California	3
(5) Connecticut	2
(6) Georgia	1
(7) Indiana	...
(8) Iowa	...
(9) Kansas	2
(10) Maryland	8
(11) Massachusetts	13
(12) Michigan	3
(13) Mississippi	2
(14) Missouri	2
(15) Montana	1
(16) Nebraska	1
(17) New Jersey	12
(18) New Mexico	2
(19) New York	2
(20) North Carolina	19
(21) Ohio	21
(22) Oklahoma	2
(23) Pennsylvania	13
(24) Texas	211 (37 over 1000 population)
(25) Wisconsin	...
(26) Virginia	4
(27) District of Columbia	

A total of 328 municipalities in the United States in 1931 had ordinances providing for sewer rental charges. It is interesting that the two states, Texas and North Carolina, containing the larger number of municipalities providing for sewer rental charges do not have a definite sewer rental law.

The sewer rental laws of fourteen states and the District of Columbia are included as Appendix A of this report. It will be observed that the majority of the laws are relatively simple, and sufficiently general to cover a wide variety of conditions.

III. Inclusiveness of State Laws as to Cost Items Covered

As pointed out in Section IV, it may be considered unfair by some to charge to the present users of the system the entire cost of such items as interest and amortization of bonds issued for the construction of a system which may be used for a long period in the future, and for which allowance is made in the design to care for the sewage from properties at present undeveloped but which, nevertheless, share in the general benefits accruing to all properties because of the construction and operation of the collection and treatment works.

Of the twelve laws included in Appendix A of this report, eight provide that complete payment of all items, such as maintenance, operation, and repair, and interest and retirement of bonds for the construction of sewerage systems and treatment works may be under a sewer rental charge, but none are mandatory as to the inclusion of fixed charges, *viz.*, interest and retirement of bonds. Most of these are worded to the effect that any surplus over what is necessary for maintenance, operation and repairs may be used; first, for interest on indebtedness and, second, for retirement of bonds. In addition, several laws provide that "none of the funds shall be used for the extension of a sewerage system to serve unsewered areas." The eight states with laws for complete payment of all operating costs by rentals are Massachusetts, New York, Michigan, Iowa, Ohio, Connecticut, North Carolina and Kansas. One state law, that of Pennsylvania, provides for coverage of operation, maintenance and repairs plus interest on indebtedness. Maryland and Washington, D. C., provide only for operation, maintenance, repair and depreciation, while the Wisconsin law includes only operation, maintenance and repair. The New Jersey law makes no mention of coverage.

State laws must of necessity be very general and inclusive on this point, leaving to the community the option of charging for whatever items it desires in the sewer rentals. Some municipalities limit their charges to include only operation, maintenance and repair, others include also interest and retirement or sinking fund charges. Mr. F. H. Waring,[51] Chief Engineer of the Ohio Department of Health, in which state 21 municipalities are operating under a sewer rental law, is quite definite on this point:

". . . the purpose of the sewer rental fund is primarily to provide for properly financing the maintenance and operation of the sewerage system and sewage treatment works; secondly, surplus funds may be used for amortization of the bonded indebtedness created for the construction of the sewage treatment and disposal works. . . . While it is possible under such a plan to include in the charges an amount to enable the retirement of sinking fund charges on bonded indebtedness for the construction of main sewerage and sewage disposal works, it seems best that the financing be limited to the maintenance and operation costs only. This is particularly true of small municipalities if the rentals are to be kept at a reasonably low figure. This conclusion is also reached when account is taken of the benefits; that is, installation of sewerage and sewage disposal benefits even vacant property by enhancement of potential value. Therefore, all property of the community should be taxed to pay for such an improvement. Operating costs are more equitably chargeable to the users of the system."

Mr. S. A. Greeley[7] makes the following statement in regard to this subject: "A sewerage system is a benefit to the health of the whole community; therefore, some proportion of its cost should be paid for by general taxation. The owner of land receives a particular benefit if a sewer is laid by his land; therefore, he should pay an assessment for this special benefit. If the cost of building the sewer is a special benefit, keeping the sewer in condition for use is a further special benefit to those who use it. Hence, a sewer rental charge is just and equitable."

IV. Methods of Making Charges for Sewerage Service

The following methods are in use as a basis of levying sewer rental charges:

(1) Flat rate charge on basis of metered water consumption.

(2) Service charges based on the size of water connection plus flowage charge (both flat rates or graduated) on metered water consumption.

(3) Graduated schedule of charges on basis of metered water consumption.

(4) Percentage surcharge on water bill.

(5) Charge on basis of assessed valuation and water consumption.

(6) General tax on basis of assessed valuation, special betterment assessment and rental charge on basis of metered water consumption.

(7) Flat rate or graduated charge on basis of metered water consumption plus flat charge on basis of type and size of dwelling, building or industry.

(8) Flat rate or graduated charge on basis of water consumption plus a charge according to the character of sewage.

(9) Flat rate or graduated charge on basis of water consumption plus a charge according to number of employes in industry.

(10) Flat rate charge according to the number and type of plumbing fixtures.

(11) Charge according to the number of persons served by sewer connection.

(12) Flat rate per sewer connection.

(13) Rate schedule based on type of sewer connection.

(14) Flate rate charge for residences and business houses.

(15) Charge according to the number of rooms in residences and business houses.

(16) Flat rate charge per lot.

(17) Charge per lineal foot of property.

(18) Charge per square foot of floor area in homes and buildings.

It will be observed that the first half of the 18 methods are based partly or entirely upon the amount of water used whereas the second half are based upon factors independent of the actual amount of water consumed.

In the selection of a basis of sewer rental, several factors should be considered, a few of which are here discussed.

The rental may be intended to defray operation and maintenance charges only or to cover all or a portion of the fixed charges as well. Since a general benefit accrues to the entire community, it is argued by some that a portion at least of the total annual charges should be paid by the municipality as a whole as in Methods 5, 6, 16 and 17; while others believe that the total annual charges of sewerage systems and treatment works should be borne by those using the system as provided by Methods 1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15 and 18.

Most authorities agree that water consumption, with allowance in certain instances for water not returned to the sewers, is a reasonably accurate measure of the use made of the sewer system, and such authorities are in accord that the amount of water used should be, where practicable, taken into consideration wherever sewer rental charges are made. There are many places, however, where for some reason it is impractical to base charges upon water consumption, and some other means must be used, as illustrated by Methods 10 to 18, inclusive.

A very important consideration which has particular reference to the Twin City situation is whether sewer rentals, if made, should or should not cover fixed charges of the treatment plant or of the treatment plant plus those of the intercepting system, *i. e.*, total annual charges. The fixed charges on the Twin City interceptors will constitute a substantial portion of the total annual charges (approximately 50%). While it is possible to make sewer rentals high enough to cover the total annual charges, it should be noted that both the sewers and treatment works will probably greatly outlive the needs of present users, and since they constitute a general

property benefit, the fixed charges should, many believe, be paid in large part by a general property tax.

A brief discussion of some of the outstanding features of the various methods for levying sewer rental charges follows:

Methods 1 to 4.—These methods, similar in that charges are made on the basis of water consumption, present a fairly accurate measure of the use made of the sewerage system. The method of providing a service charge plus a usage charge as in Method 2 has a precedent in the service charges made for electricity, steam and water.

Because a general benefit accrues to a municipality and its inhabitants due to the sewerage and sewage treatment facilities provided, regardless of whether or not they have connections to the system, a method of levying charges based solely on the water consumption is considered by some as unfair to the present users of the system, especially so if fixed charges on construction are included. They reason in the case of operation and maintenance charges that the general community benefits from having collection and treatment facilities; and in the case of fixed charges, that the works provided will still be serviceable and in use after some of the present unsewered areas are served, which property on the basis of metered water consumption only would not pay its just proportion of the cost of providing sewerage and treatment facilities.

There will be certain administrative problems to be met in the proper application of any method involving measurements of the water used. In both the private home and in a business or industrial establishment all water used is not returned to the sewers. In the case of the private home, a charge based on the summer consumption of water would not, in many instances, be a correct measure of the service rendered, since a large portion of the water supplied is then used in sprinkling and is not returned directly to the sewers. For this reason it would be desirable, if economically practical, to meter or measure the sewage flow and use that, instead of water consumption, in fixing rates for sewerage service. For certain practical and economic reasons, however, the actual metering of small quantities of sewage is not a feasible undertaking. On the other hand, the winter consumption is not a true measurement of benefits because the water consumption then is, on the average, at a lower rate than the summer consumption, exclusive of that used for sprinkling, because of the increased use during the summer for bathing, washing and general wastage, all of which is, however, returned to the sewers. Only by the installation of separate meters for lawn sprinkling services could an accurate measure of the water used for sprinkling be obtained. In many cases the cost of such an installation would not be justified. In the case of industrial use of public water supplies, not all of the water used, especially so in certain industries, is returned to the sewers for which allowance should be made in computing rental charges.

A few public services are still unmetered and some industries have their own private source of supply. In these cases, meters would have to be installed or an agreement made with the officials concerned as to a proper charge. There are 148 known private supplies in Minneapolis and 57 in St. Paul which would either have to be metered or investigated from time to time to determine the quantity of water being used and the proportion returned to the sewers.

Where the public water supply is furnished by private companies, and the records are inaccessible, it is sometimes impracticable to use water consumption as a basis of determining sewer rental charges.

Methods 5 and 6.—As already mentioned in the discussion of Methods 1 to 4, a general benefit accrues to the inhabitants of a community which provides sewerage and treatment facilities regardless of whether or not they have connections to the system, and for that reason some are of the opinion that a part of the cost of providing and operating such a system should be borne by direct taxation. On this assumption the true measure of service rendered and benefits derived might be divided into two items: general benefit and usage, the former being represented in charges by general taxation and the latter by sewer rentals. Because of the proportionally low water consumption in many office buildings, warehouses and certain commercial and industrial establishments in comparison with their assessed valuations, charges to this class of property might properly include a general property tax for the payment of at least a portion of the costs, as a general community benefit. The city of Brockton, Massachusetts, has since 1894 used this method of making charges, whereof the total amount of money collected, approximately 60%, is derived from sewer rentals and 40% from direct taxation.

Methods 7, 8 and 9.—These methods provide for making charges on the basis of water consumption but take into account, respectively, the type and size of building served, the character of the sewage and the number of employes in the industry. They represent further attempts to arrive at charges as close as possible to the costs entailed by the service rendered.

Method 10.—This method of making charges according to the number and type of plumbing fixtures, which on first thought may appear to be a compromise measure to be accepted where the metered water consumption cannot be used, has some merit. As previously stated, the volume and character of sewage contributed to the system represents a measure of cost entailed and benefits derived. Studies have been made by W. S. Tanner at Dallas, Texas, of the contribution in volume and strength from the various fixtures in homes from districts containing as many as 6000 fixtures, from which he determined that of the total pollution in residential districts 59% resulted from toilets, 16% from bathtubs, 7% from lavatories and

18% from sinks. Rates of charge for the different fixtures have been set up in a number of municipalities which are directed toward fixing equitable rates based on this type of service charge. A questionable feature of this method is that vacancies and unused fixtures are usually required to pay the regular charge.

Methods 11 to 18.—These methods of making charges are adopted usually where the water supply is not metered or where water is supplied by private companies, and charges on these bases do not always afford a direct measure of service rendered. Flat rate charges per lot or per lineal foot of property, or a charge according to the number of rooms in residences or business houses, bear but a slight relation to the quantity of sewage discharged from the property. However, these methods, especially 12, 13 and 14, have been used at a number of places.

V. Rates and Charges in Effect in Other Municipalities

Data have been collected as to rates and charges in 58 municipalities operating under sewer rental ordinances of six different types in 1931. This information is shown in Appendix B of this report and is here summarized to indicate the general range, as well as the average charges in these municipalities.

A. Charges Based Upon Metered Water Consumption.—Minimum charges range from $1.00 to $10.00 annually, with an average minimum annual charge per connection of $4.00. Schedule of water consumption charges vary from 2¢ to 30¢ per 100 cubic feet. The average charge for the first 10,000 cubic feet was at the rate of 13.5¢ per 100 cubic feet.

B. Percentage Charge of Water Bill.—Charges range from 10% to 100% of the water bill with an average in 10 municipalities of 46%.

C. Charges Included with a General Tax Levy.—General tax levies in some municipalities are combined with water consumption charges. General property tax levies range from 5¢ to 34¢ per $100 of valuation, and the average for 7 municipalities is 19¢ per $100. Front foot assessments range from 3¢ to $1.75 per foot, the average of 4 municipalities, excluding the extremes shown above, being 23¢ per front foot.

D. Flat Rate Charges, According to Number of Plumbing Fixtures.—Annual charges on the various fixtures range and average as follows:

	Range	Average
Private toilets	$1.00 to $4.00	$2.30
Public toilets	8.00 to 30.00	15.00
Kitchen sinks	1.10 to 4.00	2.70
Bathtubs	1.00 to 1.50	1.16
Lavatories		0.50
Laundry tubs	0.50 to 0.75	0.63

Charges for other fixtures as cellar and garage drains, showers, urinals, are

also set. Special charges for churches, theatres, hotels, laundries, factories and industries are sometimes made.

E. Charges Based on Number of Persons on Premises.—Charges based on the number of employes in factories and shops range from $0.75 to $1.00 for each 10 persons or less and from 30¢ to 60¢ each for all over 100 employes.

F. Flat Rate Charge on Residences and Business Houses.—Single family dwellings: Range from $3.00 to $18.00 per year with average of $7.70.

Multiple family dwellings: $4.00 per family per year.

Hotels: $1.65 per year for each room with bath.
$0.90 per year for each room without bath.

Rooming houses and fraternities: $4.00 per year plus $1.00 per year for each person.

Hospitals: $12.00 to $100 per year.

VI. Application of Sewer Rental Charges to Minneapolis and St. Paul Project

From the foregoing, it is evident that a number of methods of levying sewer rental charges are in operation in the municipalities making such charges, and that the rates for sewerage and treatment service vary widely depending on the inclusiveness of the local ordinances respecting costs to be considered, whether or not treatment is provided, the size of the municipality and other factors.

This section is presented for illustrative purposes to show the effect on the costs to the water consumers in Minneapolis and St. Paul of various methods of charging sewer rentals. Two typical methods are considered, and the effect shown on the sewer rental charges if they include (1) operation and maintenance charges alone, (2) operation and maintenance charges and fixed charges on the treatment works and (3) the total annual charges of the entire collection and treatment project. The calculations are based on 1931 data as to water consumption and revenue, assessed valuations, housing facilities, etc., and the estimated 1933 costs of this collection and treatment project.

The charges and rates which are shown must, for obvious reasons, be regarded as approximate only. They do serve, however, as a general indication of what the costs for sewerage and treatment might be under several different methods with various items of cost charged for in the sewer rental.

Method I. Sewer Rental Charges Based on Water Consumption.—The proportion here shown of the operation and maintenance charges and of the fixed charges allocated to each city has been computed according

to the terms of the bill upon which the council committees of Minneapolis and St. Paul are now working; *i. e.*,

(*a*) Each city will construct, maintain and operate all works used exclusively by it.

(*b*) For a period of 10 years the costs of all jointly used works will be apportioned upon an assessed valuation basis and thereafter the operation and maintenance charges of such works will be allocated upon a volume basis.

PER CENT WHICH THE ANNUAL COSTS OF SEWAGE COLLECTION AND TREATMENT ARE OF THE TOTAL WATER REVENUE

(1) Operation and Maintenance Charges Only		
(*a*)	Minneapolis share of operation and maintenance costs	$ 228,000.00
	Total theoretical water revenue considering private wells on same basis of charges as public supply	1,983,000.00
	Per cent of water revenue	11.5
(*b*)	St. Paul share of operation and maintenance costs	142,000.00
	Total theoretical water revenue considering private wells on the same basis of charges as public supply	1,110,000.00
	Per cent of water revenue	12.8
(*c*)	Total operation and maintenance costs	370,000.00
	Total theoretical water revenue, Minneapolis and St. Paul, considering private wells on same basis of charges as public supply	3,093,000.00
	Per cent of total water revenue	12.0
(2) Operation and Maintenance Charges Plus Fixed Charges on Sewage Treatment Plant		
(*a*)	Minneapolis share of costs	$ 452,000.00
	Per cent of water revenue	22.8
(*b*)	St. Paul share of costs	265,000.00
	Per cent of water revenue	23.9
(*c*)	Total for Minneapolis and St. Paul	717,000.00
	Per cent of total water revenue	23.2
(3) Operation and Maintenance Charges Plus Fixed Charges on Entire Project		
(*a*)	Minneapolis share of costs	$ 890,000.00
	Per cent of water revenue	44.8
(*b*)	St. Paul share of costs	$ 543,000.00
	Per cent of water revenue	49.0
(*c*)	Total for Minneapolis and St. Paul	1,433,000.00
	Per cent of water revenue	46.3

It will be noted that in (1) none of the fixed charges are taken care of in the sewer rentals, and in (2) only those of the treatment works. These fixed charges must be levied either as sewer rental or general taxes, and when not included in the rentals as in (3) they are usually added to the general property tax. The St. Paul percentages, it will be further noted, are somewhat higher than those for Minneapolis. The explanation lies in

TABLE I

EFFECT OF FLAT RATE SCHEDULE OF SEWER RENTAL CHARGES AS HEREIN COMPUTED (BASED ON METHOD I) ON THE ANNUAL COSTS TO VARIOUS CLASSES OF PROPERTY WITH DIFFERENT ITEMS OF THE COST OF SEWAGE COLLECTION AND TREATMENT INCLUDED AS SEWER RENTAL CHARGES. BASED UPON MINNEAPOLIS' SHARE OF THE COSTS AND THE PRESENT MINNEAPOLIS WATER RATE SCHEDULES. (PRESENTED FOR ILLUSTRATIVE PURPOSES.)

Class of Property*	Operation and Maintenance Charges on Sewer Rental Basis, Fixed Charges on Property Tax Basis			Operation and Maintenance Charges and Fixed Charges of Plant on Sewer Rental Basis, Fixed Charges of Intercepting Sewers on General Property Tax Basis			Total Annual Charges on Sewer Rental Basis	Total Annual Charges on General Property Tax Basis
	Sewer Rental Charge	General Property Tax	Total	Sewer Rental Charge	General Property Tax	Total		
(*a*)	$ 0.85	$ 4.00	$ 4.85	$ 1.65	$ 2.65	$ 4.30	$ 3.20	$ 5.40
(*b*)	2.10	20.00	22.10	4.10	13.30	17.40	8.00	26.90
(*c*)	41.70	20.00	61.70	82.50	13.30	95.80	161.00	26.90
(*d*)	417.00	20.00	437.00	825.00	13.30	838.30	1,610.00	26.90
(*e*)	41.70	200.00	241.70	82.50	133.00	215.50	161.00	269.00
(*f*)	417.00	200.00	617.00	825.00	133.00	958.00	1,610.00	269.00
(*g*)	4170.00	200.00	4,370.00	8,250.00	133.00	8,383.00	16,100.00	269.00
(*h*)	41.70	1000.00	1,041.70	82.50	665.00	747.50	161.00	1350.00
(*i*)	417.00	1000.00	1,417.00	825.00	665.00	1,490.00	1,610.00	1350.00
(*j*)	4170.00	1000.00	5,170.00	8,250.00	665.00	8,915.00	16,100.00	1350.00
(*k*)	8340.00	1000.00	9,340.00	16,500.00	665.00	17,165.00	32,200.00	1350.00
(*l*)	417.00	2000.00	2,417.00	825.00	1330.00	2,155.00	1,610.00	2690.00
(*m*)	4170.00	2000.00	6,170.00	8,250.00	1330.00	9,580.00	16,100.00	2690.00
(*n*)	8340.00	2000.00	10,340.00	16,500.00	1330.00	17,830.00	32,200.00	2690.00

* Note:

(*a*) $5000 home or small business establishment, assessed valuation $2000, using 200 gals. water daily.
(*b*) Business or industrial establishment, assessed valuation $10,000, using 500 gals. water daily.
(*c*) Business or industrial establishment, assessed valuation $10,000, using 10,000 gals. water daily.
(*d*) Business or industrial establishment, assessed valuation $10,000, using 100,000 gals. water daily.
(*e*) Business or industrial establishment, assessed valuation $100,000, using 10,000 gals. water daily.
(*f*) Business or industrial establishment, assessed valuation $100,000, using 100,000 gals. water daily.
(*g*) Business or industrial establishment, assessed valuation $100,000, using 1,000,000 gals. water daily.
(*h*) Business or industrial establishment, assessed valuation $500,000, using 10,000 gals. water daily.
(*i*) Business or industrial establishment, assessed valuation $500,000, using 100,000 gals. water daily.
(*j*) Business or industrial establishment, assessed valuation $500,000, using 1,000,000 gals. water daily.
(*k*) Business or industrial establishment, assessed valuation $500,000, using 2,000,000 gals. water daily.
(*l*) Business or industrial establishment, assessed valuation $1,000,000, using 100,000 gals. water daily.
(*m*) Business or industrial establishment, assessed valuation $1,000,000, using 1,000,000 gals. water daily.
(*n*) Business or industrial establishment, assessed valuation $1,000,000, using 2,000,000 gals. water daily.

TABLE II

EFFECT OF GRADUATED SCHEDULE OF SEWER RENTAL CHARGES AS HEREIN COMPUTED (BASED ON METHOD I) ON THE ANNUAL COSTS TO VARIOUS CLASSES OF PROPERTY WITH DIFFERENT ITEMS OF THE COST OF SEWAGE COLLECTION AND TREATMENT INCLUDED AS SEWER RENTAL CHARGES. BASED UPON ST. PAUL'S SHARE OF THE COSTS AND THE PRESENT ST. PAUL WATER RATE SCHEDULES. (PRESENTED FOR ILLUSTRATIVE PURPOSES.)

Class of Property*	Operation and Maintenance Charges on Sewer Rental Basis, Fixed Charges on Property Tax Basis			Operation and Maintenance Charges and Fixed Charges of Plant on Sewer Rental Basis, Fixed Charges of Intercepting Sewers on General Property Tax Basis			Total Annual Charges on Sewer Rental Basis	Total Annual Charges on General Property Tax Basis
	Sewer Rental Charge	General Property Tax	Total	Sewer Rental Charge	General Property Tax	Total		
(*a*)	$ 1.40	$ 4.50	$ 5.90	$ 2.70	$ 3.10	$ 5.80	$ 5.60	$ 6.00
(*b*)	3.20	22.30	25.50	6.05	15.40	21.45	12.40	30.10
(*c*)	40.70	22.30	63.00	76.00	15.40	91.40	156.00	30.10
(*d*)	297.00	22.30	319.30	555.00	15.40	570.40	1,136.00	30.10
(*e*)	40.70	223.00	263.70	76.00	154.00	230.00	156.00	301.00
(*f*)	297.00	223.00	520.00	555.00	154.00	709.00	1,140.00	301.00
(*g*)	2014.00	223.00	2237.00	3760.00	154.00	3914.00	7,700.00	301.00
(*h*)	40.70	1115.00	1155.70	76.00	770.00	846.00	156.00	1510.00
(*i*)	297.00	1115.00	1412.00	555.00	770.00	1325.00	1,140.00	1510.00
(*j*)	2010.00	1115.00	3125.00	3760.00	770.00	4530.00	7,700.00	1510.00
(*k*)	3860.00	1115.00	4975.00	7200.00	770.00	7970.00	14,800.00	1510.00
(*l*)	297.00	2230.00	2527.00	555.00	1540.00	2095.00	1,140.00	3010.00
(*m*)	2010.00	2230.00	4240.00	3760.00	1540.00	5300.00	7,700.00	3010.00
(*n*)	3860.00	2230.00	6090.00	7200.00	1540.00	8740.00	14,800.00	3010.00

* Note:

(*a*) $5000 home or small business establishment, assessed valuation $2000, using 200 gals. water daily.
(*b*) Business or industrial establishment, assessed valuation $10,000, using 500 gals. of water daily.
(*c*) Business or industrial establishment, assessed valuation $10,000, using 10,000 gals. water daily.
(*d*) Business or industrial establishment, assessed valuation $10,000, using 100,000 gals. water daily.
(*e*) Business or industrial establishment, assessed valuation $100,000, using 10,000 gals. water daily.
(*f*) Business or industrial establishment, assessed valuation $100,000, using 100,000 gals. water daily.
(*g*) Business or industrial establishment, assessed valuation $100,000, using 1,000,000 gals. water daily.
(*h*) Business or industrial establishment, assessed valuation $500,000, using 10,000 gals. water daily.
(*i*) Business or industrial establishment, assessed valuation $500,000, using 100,000 gals. water daily.
(*j*) Business or industrial establishment, assessed valuation $500,000, using 1,000,000 gals. water daily.
(*k*) Business or industrial establishment, assessed valuation $500,000, using 2,000,000 gals. water daily.
(*l*) Business or industrial establishment, assessed valuation $1,000,000, using 100,000 gals. water daily.
(*m*) Business or industrial establishment, assessed valuation $1,000,000, using 1,000,000 gals. water daily.
(*n*) Business or industrial establishment, assessed valuation $1,000,000, using 2,000,000 gals. water daily.

the fact that the total annual charges on the works used exclusively by St. Paul are higher proportionately than the works exclusively used in Minneapolis. The tables in this section have been prepared to show in a general way what the total costs might be to the owner of various classes of property where varying amounts of water are used.

Comparing these charges with what have been assessed at other places using this method, the general range in charges is from 10% at Winston-Salem, N. C., to 100% at Wellesley, Mass., with an average in 10 municipalities of 46%. While this value is equal to the percentage surcharge of 46% for this project when total annual charges are considered, it indicates that the sewer rental charges in these other municipalities might possibly be somewhat higher than in Minneapolis and St. Paul for the reason that the water rates in other municipalities, especially the smaller users, are probably somewhat higher than the rates here.

The water rate schedules in these two cities have, for convenience, been used as a basis of calculation to compare the effect of the application of flat rates and sliding scale schedules of sewer rental charges. The results of these calculations are shown in the following tables, Table I illustrative of a flat rate schedule, and Table II of a sliding scale schedule. These tables illustrate the effect of sewer rental charges on the annual costs to various classes of property, considering the cost items of operation and maintenance, and fixed charges on several different bases. The sewer rental charges computed for various classes of property with respect to their assessed valuations and water consumption have been hypothetically selected to illustrate the comparison in a general way of annual charges on a sewer rental and general property tax basis under these various classifications, and using the flat rate or sliding scale rate schedule.

From these tables it will be observed that the charges to the domestic consumer and the commercial and industrial consumer using small quantities of water, represented by classifications (*a*), (*b*), (*e*), (*h*) and (*l*), are lower when the sewer rental basis is utilized than when the total costs are charged on the general property tax basis. Conversely, the charges to the larger consumers of water, represented by the other classifications, are greater on the sewer rental basis than on the general property tax basis. In the comparison of the two tables, it will be seen that the charges to the large consumer of water, where a flat rate basis is applied, is greater than to consumers in the same classification where a sliding scale basis is used.

It should be noted that the rates in these tables have been computed on the assumption that the entire construction work would be financed by a bond issue, thereby necessitating higher fixed charges than if all or part of the construction work were financed by tax levies, which may or may not be the case. In any event, the fixed charges will be reduced after the bonds are retired. In addition, the costs of treatment plant operation and

maintenance are based upon year round operation at the installed capacity. As stated in the 1929 and 1930 report of this Commission: "It may be possible to decrease operating costs of an activated-sludge plant whenever dilution conditions in the river are favorable. By adjusting the aeration portion of the process to meet varying conditions in the river, reductions in power charges, labor and maintenance costs may amount to as much as 13% in 1940 and 18% in 1970 of the total annual charges of an activated-sludge plant project." For these reasons the actual costs will probably be somewhat less than those upon which the tables are based. The tables should, therefore, be considered simply as representative of the effect of sewer rental charges upon flat rate and sliding scale schedules.

Method I is based upon the use of the existing water rate charges in Minneapolis and St. Paul. As already mentioned, a number of schedules of sewer rental charges based upon rate structures quite different from the existing water rate structures in both cities might be adopted.

Sewer rental charges may be applied either as a surcharge on the water bill or an entirely different rate schedule may be used. The method of application and collection of sewer rental charges is an administrative detail. In general, two types of rate schedules are in use, one on a flat rate basis, the other on a sliding scale basis. The present Minneapolis water bills are based on a flat rate charge with a schedule of minimum charges, whereas the St. Paul rates are on a sliding scale with separate meter charges.

While a variety of rate schedules might be set up to cover charges of sewage collection and treatment, the present water rate structures used in Minneapolis and St. Paul, although quite different, are herein used for illustrative purposes as a basis of calculation. The following schedule of sewer rental rates, presented for illustrative purposes only, indicates the surcharges on the present water rates using the flat rate schedule of charges as exemplified by the present Minneapolis water bills, and the graduated schedule of charges as used in St. Paul.

MINNEAPOLIS—MINIMUM QUARTERLY CHARGE

Meter Size	Present Water Bill	Sewer Rental Surcharge—Operation and Maintenance Charges Only, Included	Sewer Rental Surcharge—Total Annual Charges, Included
5/8"	$ 1.00	$0.12	$ 0.45
3/4"	1.50	0.17	0.67
1"	2.50	0.29	1.12
1 1/2"	5.00	0.58	2.24
2"	8.00	0.92	3.58
3"	16.00	1.84	7.17
4"	25.00	2.87	11.20
6"	50.00	5.75	22.40
8"	80.00	9.20	35.90
Rate per 100 cubic feet, cents	7 1/2	0.86	3.36

ST. PAUL—MONTHLY DEMAND OR SERVICE CHARGE

Meter Size	Present Water Bill	Monthly Sewer Rental Surcharge: Operation and Maintenance Charges Only, Included	Monthly Sewer Rental Surcharge: Total Annual Charges, Included
5/8"	$ 0.25	$0.03	$ 0.12
3/4"	0.35	0.04	0.17
1"	0.60	0.08	0.29
1 1/4"	0.85	0.11	0.42
1 1/2"	1.10	0.14	0.54
2"	2.25	0.29	1.10
3"	5.00	0.64	2.45
4"	10.00	1.28	4.90
6"	20.00	2.56	9.80
8"	35.00	4.48	17.15
10"	50.00	6.40	24.50
Meter rate per 100 cubic feet, cents			
First 10,000 cu. ft. per month	9.0	1.15	4.41
Next 40,000 cu. ft. per mo.	6.0	0.77	2.94
Next 450,000 cu. ft. per mo.	4.5	0.58	2.21
All over 500,000 cu. ft. per mo.	3.0	0.38	1.47

The sewer rental rates shown compare with an average charge of 13.5¢ per 100 cubic feet in 17 municipalities making a sewer rental charge on this basis.

Method II. Fixture Charges for Domestic and Metered Water Rate for Commercial and Industrial Contributors.—A number of municipalities levy sewer rental charges on the basis of the plumbing fixtures in each building, with a schedule of rates for the various types of fixtures. One schedule of rentals on this basis—a variety might be set up—has been calculated in an approximate way to show what the charges might be in Minneapolis and St. Paul under such a method. Based on data supplied by the Minneapolis Planning Commission and the County Assessor's office in St. Paul, the total family capacity of single residences, duplexes and apartment buildings in Minneapolis and St. Paul, in 1931, was approximately 169,000. If each residence or apartment had one each of the following fixtures, the annual charges per fixture might be somewhat as shown in the following tabulation.

Fixture	Operation and Maintenance Charges Only	Total Annual Charges
Toilet	$0.38	$1.48
Sink	0.38	1.48
Bathtub	0.19	0.74
Lavatory	0.08	0.30
Laundry	0.08	0.30

The total annual charges per family having one of each type of fixture are $1.10 to $4.30.

These annual fixture rentals would be reduced by charges which might be made for showers, cellar drains and because of duplicity of fixtures. These rates must be considered as approximate only because of the lack of information on the actual number of fixtures of all types. In addition to these charges, rates for commercial and industrial service similar to those set forth under Method I are assumed.

These charges compare with the following annual charges in eight municipalities using this method of charging sewer rentals:

Toilets	$2.30
Kitchen sinks	2.70
Bathtubs	1.16
Lavatories	0.50
Laundry tubs	0.63
Total charge per family with one each	= $7.29

Qualifying Statements.—As already mentioned, the preceding data as to rates are based on the estimated costs of the intercepting sewers and treatment works necessary to the collection and treatment of the sewage from the existing trunk sewers in both cities, and is based upon 1931 water consumption, revenues and assessed valuations. Because of the lack of available data on a number of factors such as, for example, the percentage of the water supply of commercial and industrial consumers not returned to the sewers, the actual private water consumption, etc., the calculations must be regarded as approximate.

Furthermore, the sewer rental charges which are set up in this report are based on the costs of collection and treatment necessitated by the construction and operation of intercepting sewers and treatment works, and do not consider in any respect the costs of the existing independent sewerage systems in both cities. It is the practice in a number of municipalities applying sewer rental charges to include either the costs of operation, or the total costs, including interest and amortization of the entire sewerage system, in its charges.

If the operation and maintenance costs of the existing sewerage systems in the two cities, amounting to about $150,000 annually in the last several years, are added to the costs of the intercepting sewers and treatment plant as considered in this report, the charges would be increased by an amount equivalent to 4.85% of the present water bills.

VII. Advantages and Disadvantages of Sewer Rental Plan

Some of the reasons usually advanced for the establishment of sewer rental charges, in addition to the equity of proper charges for sewerage service, are that they provide a continuous fund for the operation, maintenance and repair of existing systems, thereby permitting capable and

efficient operation unimpaired by shortage of general tax funds due to decreased valuations, or because of diversion of funds for other purposes. A further reason for the interest in sewer rental charges, which is especially alive at this time, is the possibility of obtaining federal loans through the Reconstruction Finance Corporation on self-liquidating projects which are generally interpreted as requiring the placing of the collection and treatment system on a utility basis and levying sewer rental charges of some type. The following statement of advantages and disadvantages of annual charges for sewerage service, extracted from a paper by Frank A. Marston,[32] presents observations on both sides of this question.

Objections to Annual Charges for Sewerage Service

"The following are the usual objections that have been raised in discussions of the subject:

"(*a*) It is difficult to gain public approval of such a plan unless a new sewerage system or sewage treatment plant is just being started.

"(*b*) Such a system requires clerical assistance and involves expense and other complications of administration.

"(*c*) Some property owners prefer to pay one bill for taxes rather than to have a separate bill for sewerage service. Some property owners may delay making a sewer connection, until forced to do so by ordinance, because of the desire to escape the annual charges as long as possible.

"(*d*) Service charges cannot be billed until the sewer connection has been made and the sewer is ready to use, and any unforeseen delays in construction may delay the receipt of funds, thereby throwing an unexpected burden on other sources of revenue. This applies particularly to the first year or two after starting to build the system.

"(*e*) A residential community may not require the various classification of service justified in an industrial city and for that reason the complications of a service charge system may appear unwarranted.

"(*f*) The municipality as a whole should bear a substantial part of the cost of operating the system."

Advantages of Annual Charges for Sewerage Service

"The advantages to be derived by a system of annual charges are of special significance where there is a sewage treatment plant. Briefly, they are as follows:

"(*a*) Funds can be provided continuously and adequately to ensure efficient operation and the best service.

"(*b*) The source of revenue will not be in direct competition with other more popular budget items in the tax levy.

"(*c*) The funds will not be subject to economy cuts at the whims of disinterested officials.

"(*d*) Each property owner will pay a fair share of the cost in accordance with use.

"(*e*) Taxpayers having no sewerage facilities will not be required to pay for maintaining the service rendered others.

"(*f*) The sewerage works can be maintained in efficient condition and thereby avoid waste of public property.

"(*g*) Keeping the sewage treatment plant in good operating condition will avoid the danger of lawsuits because of pollution from the discharge of untreated sewage or other nuisance that might result under conditions of bad operation.

"(*h*) The availability of funds will permit engaging trained operators and adequate labor, thus ensuring good operation.

"(*i*) The sewerage system will be a self-supporting public utility comparable with the water system.

"(*j*) Funds will be limited in use to the purposes intended and cannot be diverted to other municipal departments.

"While there may be some theoretical justification for paying sewerage service out of taxes, the fact remains that many sewage treatment plants have been ruined for lack of proper operating funds, whereas such funds might have been provided through a suitable system of annual service charges. That there is merit in such a plan is evidenced by the increasing interest in the subject and in the number of cities adopting the system."

APPENDIX A

Sewer Rental Laws in Effect in Other States

The following laws in reference to charges for sewerage service adopted in Massachusetts, New York, Pennsylvania, Michigan, Iowa, Ohio, Wisconsin, Connecticut, New Jersey, North Carolina, Maryland, Kansas, Indiana and Washington, D. C., are included as typical laws of this type.

MASSACHUSETTS, General Laws, Chapter 83, Section 16, 1892. The aldermen of any city except Boston, or the sewer commissioners, selectmen or road commissioners of a town, may from time to time establish just and equitable annual charges for the use of common sewers, which shall be paid by every person who enters his particular sewage therein. The money so received may be applied to the payment of the cost of maintenance and repairs of such sewers or of any debt contracted for sewer purposes.

NEW YORK, L1929, Chapter 225, Section 279, Article XI. The board of trustees of any village which has installed or is installing for public use a sewerage system including some form of sewage treatment plant may establish by resolution a scale of rents to be called "sewer rents," to be paid at such times and in such manner as the board may prescribe. Such rents may be based upon either the metered consumption of water on premises connected with the sewer system making due allowances for commercial use of water, the number and kind of plumbing fixtures connected with the sewer system or the number of persons served by said sewer system or may be determined by the board of trustees upon any other equitable basis. The board of trustees

may change the rates of such rents from time to time as may be deemed advisable. Such rents shall constitute a lien upon the real property served by sewers, and such a lien is prior and superior to every other lien or claim, except the lien of an existing tax, water rent or local assessment, and the board of trustees may bring and maintain an action in the name of the village for the foreclosure of such liens for such sewer rents. The funds received from the collection of sewer rentals shall be kept as a separate and distinct fund and shall be known as the sewer fund. This fund shall be used for the payment of the cost of the management, maintenance and operation and repair of the sewerage system including treatment and disposal works, and any surplus in such fund may be used for the enlargement or replacement of the same and for the payment of the interest on any debt incurred for the construction of such sewerage system, including sewage pumping, treatment and disposal works, and for retiring such debt, but shall not be used for the extension of a sewerage system to serve unsewered areas or any purpose other than one or more of these above specified.

PENNSYLVANIA, Section 2170. Ordinance for Annual Rental. Whenever any borough has constructed any sewer or sewer system, or has acquired wholly or partially the same at public expense, the council of such borough may provide, by ordinance, for the collection of an annual rental or charge, for the use of such sewer system, from the owner of property served by it. The council may, at its discretion, in lieu of such annual rental or charge, provide for the payment by such owner of a fixed sum.

Section 2171. How Rental Fixed. Such annual rental shall not exceed the amount expended annually by the borough in the maintenance, repair, alteration, inspection, depreciation or other expense, in relation to such sewer or sewer system, and may include any interest on money expended by the borough in the construction of the sewer or sewer system. The said annual or fixed sum shall be apportioned equitably among the several properties served by the said sewers.

Section 2172. Collection of Rental. Such annual rental or charge, or fixed sum, shall be authorized and collected as provided by general ordinances, and, when so levied and charged, shall be a lien on the properties charged. The collection thereof shall be made and enforced in the manner municipal claims are now or may hereafter be collected.

The councils of such borough shall execute a warrant or warrants, authorizing the collection of such annual sewer rentals or charges, or such fixed sum, to the officer employed by council to collect the same. Such officer shall have the authority now vested by law for the collection of borough taxes.

Section 2173. Lien. Such annual sewer rentals or charges, or fixed sum, shall be a lien on the properties charged with the payment thereof, from the date set forth in the ordinance, and, if not paid after thirty days' notice, may be collected by an action of assumpsit, in the name of the borough against the owner of the property charged, or by distress of personal property on the premises, or by a lien filed in the nature of a municipal lien.

MICHIGAN, Act 160, Amended 1929. The legislative body of any such governmental agency or municipality or the respective legislative bodies of such governmental agencies and municipalities, who may have agreed to jointly own and operate intercepting sewers or sewage treatment plants, may create a separate board or may designate certain officials of the governmental agencies or municipalities to have the supervision and control of such intercepting sewers or sewage and garbage disposal plants. The legislative body, respective legislative bodies, or such board may make all necessary rules and regulations governing the use, operation and control thereof. The legislative body or respective legislative bodies may establish just and equitable rates or charges to be paid to them for the use of such disposal plant and system by each person, firm or

corporation whose premises are served thereby. If the service charge so established is not paid when due, such sum may be recovered by the governmental agencies or municipalities in an action of assumpsit, or it may be certified to the tax assessor and assessed against the premises served, and collected or returned in the same manner as other county or municipal taxes are certified, assessed, collected and returned.

Bonds which are issued and secured by a mortgage on the utility as hereinbefore provided shall not be a general obligation of the governmental agencies or municipalities, but shall be paid only out of revenues received from the service charges as provided in the preceding section, or from a sale of the property and franchises under a foreclosure of the mortgage. If a service rate is charged, to be paid as herein provided, such portion thereof as may be deemed sufficient shall be set aside as a sinking fund for the payment of the interest on said bonds, and the principal thereof at maturity.

Governmental agencies or municipalities as herein mentioned instead of owning and operating a sewer system and sewage disposal plant, garbage collection and disposal system, as herein provided, may grant a franchise for a period not to exceed thirty years to any private corporation organized under, or authorized by the laws of this state to engage in such business, to build, construct, own and operate a sewage or garbage disposal system for the purpose of receiving and treating sewage and night soil and garbage as hereinbefore mentioned from such governmental agencies or municipalities. Such franchise may authorize the corporation to charge each person, firm or corporation owning property from which such a sewage or garbage is received such a fee therefor as may be determined to be reasonable by the public utilities commission of this state, upon proper application made either by such corporation, governmental agencies or municipalities, and after a hearing thereon. Such franchise may also grant to the corporation the right and privilege to lay all such necessary intercepting and other sewers and connecting pipes in the streets and public alleys of the governmental agencies or of the municipalities as may be necessary to receive and conduct the sewage to the disposal plant and under such reasonable rules, regulations and supervision as may be established by the governmental agencies or the municipalities. Any such franchise shall be void unless approved by three-fifths of the electors of such governmental agencies or municipalities voting thereon at any general or special election.

Any such governmental agencies or municipalities may enter into a contract with any corporation organized under or authorized by the laws of this state to engage in the business herein mentioned, to receive and treat in the manner hereinbefore mentioned the sewage, night soil and garbage thereof. Such contract may authorize the corporation to charge the owners of the premises served such service rate therefor as the public utilities commission of this state may determine to be just and reasonable, or the governmental agencies or municipalities may contract to pay the said corporation a flat rate for such service, and pay therefor out of their general fund or assess the owners of the property served a reasonable charge therefor to be collected as hereinbefore provided and paid into a fund to be used to defray such contract charges.

IOWA, Chapter 157, Senate File 327, 1931. Sewer Rentals.

Section 1. The city or town council of any city or town which has installed or is installing sewerage, a system of sewerage, sewage pumping stations or sewage treatment or purification works, any and all of which are hereinafter termed sanitary utilities, for public use, and which has by ordinance established one or more sewer districts in compliance with section fifty-nine hundred eighty-four (5984) of the code of 1927, may by ordinance establish just and equitable rates of charges or rentals to be paid to such city or town for the use of such sanitary utilities by every person, firm or corporation whose premises are served by a connection to such sanitary utilities directly or indirectly. Such charges shall be as nearly as may be in the judgment of the council equitable and

in proportion to the service rendered, and taking into consideration only in the case of each such premises the quantity of sewage therein or thereby produced and its concentration, strength or river pollution qualities in general. Such charges shall constitute a lien upon the property served by such sanitary utility and if not paid when due as by said ordinance provided, shall be collected in the same manner as other taxes. The council may change the rates or charges or rentals from time to time as may seem advisable. The council may provide in said ordinance for the management of said sanitary utility and the collection of said rates, rentals or charges.

Section 2. Said charges may be collected at the same time, place and in conjunction with the water rentals in any city or town owning and operating the municipal water supply and distribution system.

Section 3. Said ordinance may provide for the metering of private water supplies produced or operated on premises served by such sanitary utility.

Section 4. Said sewer rentals, charges or rates may supplant or replace in whole or in part millage levy taxes which may have been authorized by resolution of any city or town council to meet interest, and/or principal payments on bonds legally authorized for the financing of such sanitary utilities, and when such sewer rental ordinance has been duly passed and put into effect, such prior ordinances or resolutions providing for millage taxes against real and personal property for such purpose, or the portion thereof thus replaced, may be rescinded, repealed or rendered inactive.

Section 5. Any and all funds, fees, rentals, charges or rates collected under the provisions of this section shall be remitted or turned over to the city treasurer by the officer charged with their collection at least once each month, and all such collections shall be kept in a separate and distinct fund to be known as the sewer rental fund, and disbursed only upon resolution of the council and used only for the purpose of paying the cost of financing the operation, maintenance and/or construction of the sanitary utility herein defined.

Section 6. In no case shall such sewer charges, rentals or rates or the funds accruing from the collection thereof be used to meet the cost of construction, maintenance or operation of lateral sewers serving purely local territory, or the portion of the cost of sanitary utilities as herein defined, which have been financed by special assessment against benefited properties.

OHIO, Section 3891—1923. Sewer Rental Law.

Section 3891-1. The council of any city or village which has installed or is installing sewerage, a system of sewerage, sewage pumping works or sewage treatment or disposal works for public use may by ordinance establish just and equitable rates or charges of rents to be paid to such city or village for the use of such sewerage, a system of sewerage, sewage pumping works or sewage treatment or disposal works by every person, firm or corporation whose premises are served by a connection to such sewerage, system of sewerage, sewage pumping works or sewage treatment or disposal works. Such charges shall constitute a lien upon the property served by such connection and if not paid when due shall be collected in the same manner as other city and village taxes. The council may change such rates or charges from time to time as may be deemed advisable; provided, however, that in a municipality operating under a municipal charter the council or other legislative body may establish the schedule of rates herein authorized and provide for its administration by designating the department or officer of the municipality to be charged with the enforcement of the provisions of this act.

Section 3891-2. In a city the director of public service shall manage, conduct and control the sewerage system and sewage pumping, treatment and disposal works and

when the council has established a schedule of rates or charges of rents for their use shall collect sewer rentals, and he shall appoint the necessary officers for such purposes.

Section 3891-3. When the council of a village has established a schedule of rates or charges of rents for the use of the sewerage system and sewerage pumping, treatment and disposal works, the board of trustees of public affairs shall manage, conduct and control such sewerage system and sewage pumping, treatment and disposal works and shall collect sewer rentals and shall appoint necessary officers and agents for such purposes; and shall assume all duties in relation to sewers, imposed upon the street commissioner by Section 4364 of the General Code, whereupon the street commissioner shall be relieved of such duties.

Section 3891-4. The director of public service and the board of trustees of public affairs may make such by-laws and regulations as may be deemed necessary for the safe, economical and efficient management and protection of the sewerage system and sewage pumping, treatment and disposal works; and for the construction and use of house sewers and connections to the sewerage system. Such by-laws and regulations shall have the same force and effect as ordinances when not repugnant thereto or to the constitution or laws of the state.

Section 3891-5. The funds received from the collection of sewer rentals shall be deposited weekly with the treasurer of the corporation. Money so deposited shall be kept as a separate and distinct fund and shall be known as the sewer fund. When appropriated by council, it shall be subject to the order of the director of public service of a city or board of trustees of public affairs of a village. Such director or board shall sign all orders drawn on the treasurer of the corporation against such fund. This fund shall be used for the payment of the cost of the management, maintenance, operation and repair of the sewerage system and sewage pumping, treatment and disposal works, and any surplus in such fund may be used for the enlargement or replacement of the same and for the payment of the interest on any debt incurred for the construction of such sewerage system and sewage pumping, treatment and disposal works, and for the creation of a sinking fund for the payment of such debt, but shall not be used for the extension of a sewerage system to serve unsewered areas or for any other purpose whatsoever.

Section 3891-6. That section 4357 of the General Code shall be amended to read as follows:

Section 4357. In each village in which water works, an electric light plant or artificial or natural gas plant, or other similar public utility is situated, or when the council orders water works, an electric light plant, natural or artificial gas plant, or other similar public utility, to be constructed or to be leased or purchased from any individual, company, or corporation, or when the council shall have determined to establish a schedule of rates or charges of rents for use of the sewerage system and sewage pumping, treatment and disposal works of the village, the council shall establish at such time a board of trustees of public affairs for the village, which shall consist of three members, residents of the village, who shall be each elected for a term of two years.

WISCONSIN, Section (66.06) (22), 1931. Sewer Rental Law. A new subsection is added to section 66.06 of the statutes to read: (66.06) (22) (*a*). Any town, village or city which shall have installed or shall install, pursuant to the approval of the State Board of Health, a plant for the treatment or disposal of sewage may establish and collect from the respective owners of the property which is served directly or indirectly by said plant reasonable rental charges, and, for the purpose of making such rental charges equitable, may classify the property benefited thereby, taking into consideration the volume and character of the sewage or waste and the nature of the use made of such sewerage facilities. Said rental charges shall be collected or taxed against the property

in like manner as water rates are collected and taxed under the provisions of paragraphs (*a*) and (*b*) of subsection (11) of section 66.06. The income derived from such rentals shall be kept in a special trust fund by the municipal treasurer subject only to disbursement by order of the municipal council for the operation, maintenance and repair of the municipal sewerage system and sewage treatment works.

(*b*) Any twenty-five or more freeholders of such a municipality may file complaint with the railroad commission to the effect that the rental charges so fixed are unreasonable or unjustly discriminatory, and the railroad commission shall, after public hearing thereon, file its findings and determination stating therein in what respect, if any, said rental charges are unreasonable or unjustly discriminatory, and the municipality at interest shall forwith readjust its rental charges so as to remove any unreasonable or unjustly discriminatory features so found by the railroad commission. Any party in interest may appeal from the findings and determination of the railroad commission in like manner as provided in sections 196.41 to 196.48.

CONNECTICUT, House Bill No. 696, 1931.

Section 3. The legislative body of any such town, city or borough or sewer or other district organized for municipal purposes, individually, or the respective legislative bodies of such towns, cities or boroughs or sewer or other districts organized for municipal purposes, which may have agreed to own and operate jointly sewers or sewage treatment plants may create a separate board or may designate certain officials of the respective towns, cities or boroughs or sewer and other districts organized for municipal purposes, to supervise and control such sewers and sewage treatment plants. The legislative body, respective legislative bodies or such board may make all necessary rules and regulations governing the use, operation and control thereof. The legislative body, respective legislative bodies or such board may establish just and equitable rates or charges to be paid for the connection with and use of such systems or disposal plants by any such person, firm or corporation whose premises are served thereby. If the service charge so established shall not be paid when due, such sum with interest thereon at a rate not to exceed six per centum may be recovered from date of maturity by the town, city or borough or sewer or other district organized for municipal purposes in a legal action instituted in the name of such town, city or borough or sewer or other district organized for municipal purposes in a legal action instituted in the name of such town, city, or borough or sewer or other district organized for municipal purposes, or it may be certified to the respective tax assessors and assessed against the premises served and collected and retained by lien or otherwise in the same manner as other taxes are certified, assessed, liened, collected and returned. Any funds collected under the above provisions of this act shall be used for the equipment, operation and maintenance of existing systems and treatment plants and for the payment of interest on, and the principal at maturity of, any bonds, the proceeds of the sale of which were invested in acquiring, constructing and equiping the existing systems and treatment plants. No part whatsoever of funds so collected shall be used for the extension of the sewerage system into unsewered areas.

Section 5. All assessments shall be made on the basis of particular or collective benefits to those directly or indirectly benefited. Any material increase in benefits shall warrant an additional assessment. For equal benefits as determined by said legislative body in the same fiscal year or from the same project, there shall be a like assessment.

Section 6. Before any assessment shall become final, the owner of the property to be assessed shall be given not less than seven days' notice of a hearing thereon, such notice to be sent by mail to the last reported address of such owner. At such hearing to be held by the legislative body within the territorial limits of the approved project,

such property owner may appear and be heard relative to the proposed assessment of his property. The legislative body shall thereupon determine the assessment to be levied against each such property and such assessment shall thereupon be final, provided any property owner aggrieved by such assessment shall have the right to appeal to the superior court within the county where such property is assessed. Such appeal shall not be valid unless brought to the next return day of said court, or the next but one, and within fifteen days after the final assessment is made. Said court may appoint three disinterested persons to appraise the benefits to such property and make a report of their doings to the court. The judgment of said court, either confirming or altering such assessment, shall be final. Such appeal, during the pendency thereof, shall stay further proceedings for the collection of the particular assessment upon which the appeal is predicated, but shall not stay any other proceedings in relation to such project. Any assessment made in conformity with this act shall be a lien against such property, and shall be collected by the legislative body or its designated collector in the manner provided by statute for the collection of taxes.

Section 8. Assessments shall be due and payable at such time as may be fixed by the legislative body of any town, city or borough or sewer or other district organized for municipal purposes, provided, for just and reasonable cause, payment of any assessment or part thereof may be deferred by such legislative body for a period not to exceed one year, and such deferred payment shall bear interest at a rate not to exceed six per centum per annum from the date when it was so payable.

Section 9. Upon the application, in writing, to the legislative body of any town, city or borough or sewer or other district organized for municipal purposes, received from any person against whom an assessment has been levied, at any time before it becomes due, an apportionment may be made by such legislative body of such assessment in such number of annual installments, not exceeding ten, as the person affected may request. The payment of the first installment of such apportionment shall be made at the time the entire assessment is due. Interest upon the remaining installments, from the date the entire assessment is due, at a rate not to exceed six per centum per annum shall be added to each installment until paid. Nothing herein contained shall be construed to prevent the payment in full at any time in one payment, notwithstanding its prior apportionment, of any balance of any assessment remaining unpaid, but interest on the balance at not to exceed six per centum per annum shall be due and payable to the date of such payment.

Section 10. If any clause, sentence, paragraph, section or part of this act shall be adjudged invalid by any court of competent jurisdiction, such judgment shall not affect, impair or invalidate the remainder of this act.

Section 11. Nothing in this act contained, or interpreted to contain, shall prevent any town, city or borough or sewer or other district organized for municipal purposes, should it so elect, securing from the general assembly a special act enabling it to plan, finance, construct, operate and maintain sewers and sewage treatment plants.

Section 12. This act shall take effect from its passage.

NEW JERSEY, Chapter 152, Art. 21, P. G. of 1917. The governing body of every municipality owning or controlling sewers or drains shall have the entire control and management of sewers and drains in such municipality, and shall have power, by ordinance, to prescribe such charges, rules, rentals, regulations, conditions and restrictions as to the connection with and the use of such sewers and drains, as in their opinion may be proper and necessary.

The charges for connections with and rental for the use of sewers and drains so fixed by said governing body shall draw the same interest from the time they become due, and shall be and remain, until paid, a lien upon the premises with which such sewer

or drain is connected, the same as taxes upon real estate; and said municipality shall have the same remedies for the collection of said charges and rents, with interest, costs and penalties, as the said municipality has by law for the collection of taxes upon real estate.

NORTH CAROLINA, Chapter 100 Public Laws of North Carolina, Session of 1927 Providing for Creation of Sanitary Districts. A Sanitary District Board shall immediately upon the placing into service of any of its works apply service charges and rates which shall, as nearly as practicable, be based upon the exact benefits derived. Such service charges and rates shall be sufficient to provide funds for the proper maintenance, and adequate depreciation and operation of the work of the district. Any surplus from operating revenues shall be set aside as a separate fund to be applied to the payment of interest on bonds, to the retirment of bonds or both. As the necessity arises the Sanitary District Board may modify and adjust such service charges and rates from time to time.

MARYLAND, Chapter 641, Section 348O, 1927. For the purpose of providing funds for maintaining, repairing and operating water supply, sewerage, drainage and refuse disposal systems constructed under the provisions of Section 348A–348B, including overhead expense and proper depreciation allowance, municipal authorities shall have full power and authority to make such service rates as they may deem necessary, chargeable against all properties served by a water main, sewer, drain or refuse disposal system under their ownership. Service rates shall be subject to change from time to time as said authorities deem necessary. Said rates shall be payable at such times, and shall be subject to such penalties for non-payment, as said authorities may determine, and they shall be collectable against the owner of the property served, in the same manner as other debts are collectable at law.

KANSAS, Chapter 136, 1929.

15-714. Rate and Charges for Connections with Sewerage System. That the governing body of any city of the third class may by ordinance fix such rates and charges for the connections with and use of the sewer or sewer systems of said city as may be just, reasonable and necessary and provide for the manner of the making and collection of the same. (L. 1929, ch. 136, § 1, May 28.)

15-715. Revenue Derived; Limitations. The revenue derived from the making of connections to said sewer or sewer systems and the rental for the use of said sewer and sewer systems shall be placed in the city treasury and kept in a separate fund, and shall not be paid out nor distributed except for the purpose of operating, renewing or extending the sewer system and the payment of the salaries of employees engaged in operating said sewer system, and at any time there may be a surplus of such fund, it shall be semi-annually placed in a sinking fund for the purpose of acquiring, renewing or extending said sewer system or making renewals or extensions thereto, or for retiring the bonded indebtedness upon said sewer system: *Provided*, That in the event that said surplus fund shall be used to retire outstanding sewer bonds, the same shall be in addition to the money derived by taxation for such retirement of sewer bonds as is now provided by law: *Provided further*, That when any surplus fund is not needed for any of the above mentioned purposes, said surplus may be merged into the city general fund. (L. 1929, ch. 136, § 2, May 28.)

15-716. Nonpayment of rates; Placed on Tax Roll. That in the event that any person, firm or corporation using said sewer system shall neglect, fail or refuse to pay the rates and charges fixed by said governing body for the connection with and use of said sewer, said person, firm or corporation shall not be disconnected from said sewer system or refused the use of said sewer, but said rates and charges due therefor shall be by the city clerk certified to the county clerk of the county in which said city is located, to be placed on the tax roll for collection, subject to the same penalties and collected in

like manner as other taxes are by law collectable, and shall become a lien upon the real property so served by said sewer connection. (L. 1929, ch. 136, § 3, May 28.)

INDIANA, Special Session Law, 1932. Section 14. The common council of the city, or the board of trustees of the town, shall have power, and it shall be its duty, by ordinance to establish just and equitable rates or charges for the use of and the service rendered by such works to be paid by the owner of each and every lot, parcel of real estate or building that is connected with and uses such works by or through any part of the sewerage system of the city or town, or that in any way uses or is served by such works and may change and readjust such rates or charges from time to time. Such rates or charges shall be sufficient in each year for the payment of the proper and reasonable expense of operation, repair, replacements and maintenance of the works and for the payment of the sums herein required to be paid into the sinking fund. Revenues collected pursuant to this section shall be deemed the revenues of the works. No such rates or charges shall be established until after a public hearing, at which all the users of the works and owners of property served or to be served thereby and others interested shall have opportunity to be heard concerning the proposed rates or charges. After introduction of the ordinance fixing such rates or charges, and before the same is finally enacted, notice of such hearing, setting forth the proposed schedule of such rates or charges, shall be given by one publication in a newspaper published in the city or town, if there be such a newspaper, but otherwise in a newspaper having general circulation therein, at least ten days before the date fixed in such notice for the hearing, which may be adjourned from time to time. After such hearing the ordinance establishing rates or charges, either as originally introduced or as modified and amended, shall be passed and put into effect. A copy of the schedule of such rates and charges so established shall be kept on file in the office of the board having charge of the operation of such works, and also in the office of the city clerk or town clerk, and shall be open to inspection by all parties interested. The rates or charges so established for any class of users or property served shall be extended to cover any additional premises thereafter served which fall within the same class, without the necessity of any hearing or notice. Any change or readjustment of such rates or charges may be made in the same manner as such rates or charges were originally established as hereinabove provided: Provided, however, That if such change or readjustment be made substantially pro rata as to all classes of service, no hearing or notice shall be required. The aggregate of the rates or charges shall always be sufficient for such expense of operation, repair and maintenance and for such sinking fund payments. If any service rate or charge so established shall not be paid within thirty days after the same is due, the amount thereof, together with a penalty of ten per centum, and a reasonable attorney's fee, may be recovered by the board in a civil action in the name of the city or town.

Section 15. The city or town shall be subject to the same charges and rates established as hereinabove provided, or to charges and rates established in harmony therewith, for service rendered the city or town, and shall pay such rates or charges when due and the same shall be deemed to be a part of the revenues of the works as herein defined, and be applied as herein provided for the application of such revenues.

WASHINGTON SUBURBAN SANITARY DISTRICT, Chapter 122, 1918. Section 13. That for the purposes of providing funds for maintaining, repairing and operating its water supply, sewerage and drainage systems, including overhead expenses and proper depreciation allowance, together with funds for making such payments as may be made on the commissioners of the District of Columbia as hereinafter specified, said Commission shall be empowered and directed to make such service rates as it may deem necessary, chargeable against all properties having a connection with any water pipe under its ownership. Said rates shall be uniform throughout the Sanitary

District, but subject to change from time to time, as necessary, except that the charge for water used in Gaithersburg and Washington Grove, until such time as they are brought within the general system, shall be based upon the actual cost of supplying water to said communities. The rates for service shall consist of a minimum or ready-to-serve charge, which shall be based upon the size of the meter on the water connection leading to the property, and of a charge for the water used, which shall be based upon the amount of water passing the meter during the period between the last two readings, said meter being required to be placed on each water connection by, and at the expense of, the Commission....

APPENDIX B

Rates and Charges for Sewer Rentals in Various Municipalities*

The following information has been collected from the literature as to sewer rental charges collected in 58 municipalities in the United States making such charges. While far from complete, the data shows in a general way the rates charged under six different methods of assessing the cost of sewage collection and treatment under the sewer rental plan.

A. Charge Based Upon Metered Water Consumption.

(1) *Columbiana, Ohio*

$2^1/_2$ cents per 1000 gallons per quarter. Minimum charge $1.25 per quarter. With private supplies of unmetered water, a flat rate based on fixtures is charged. (See 1, Sec. D).

(2) *Lima, Ohio*

1st 500 cu. ft. of water 80¢ per quarter (90¢ outside city). Each 1000 cu. ft. in excess of 500, 15¢ per 1000 (20¢ outside city). Private water supplies are to be metered if practical, or measured in some manner by the Supt. of Sewage Treatment Works. Industrial wastes may also be measured and charged for. Schools, city, county, state or federal property, together with non-profit hospitals, are exempt from charge.

(3) *Bellefontaine, Ohio*

Public garages and wash racks: 25¢ per 1000 cu. ft. water. Public schools: 25¢ per 1000 cu. ft. of water. See Sec. D, E and F for other charges.

(4) *Oberlin, Ohio*

First 10,000 cu. ft. @ 90¢ per 1000 cu. ft. All over 10,000 cu. ft. @ 80¢ per 1000 cu. ft. Minimum $1.25 per service per quarter. 10% penalty for failure to pay promptly.

(5) *Mason, Michigan*

For all premises having metered water service: $12^1/_2$¢ per 1000 gallons, provided water consumption does not exceed 5,000,000 gallons per annum. Minimum charge $1.00 per annum. 20% discount for prompt payment. See Sec. F for other charges. (Ordinance now repealed and unjustly so, according to State Board of Health.)

(6) *Oxford, Ohio*

25¢ per 1000 cu. ft. of water consumed per quarter year, with a minimum charge of $1.25 per quarter year for each sewer service.

* *Information compiled by K. L. Mick, Chemical Engineer, Metropolitan Drainage Commission.*

(7) *Dayton, Ohio*

First 3000 cu. ft.		$1.00 per quarter year.
Between 3,000 and	10,000 cu. ft.	0.30 per quarter year per 1000 cu. ft.
Between 10,000 and	20,000 cu. ft.	0.25 per quarter year per 1000 cu. ft.
Between 20,000 and	100,000 cu. ft.	0.20 per quarter year per 1000 cu. ft.
Between 100,000 and	500,000 cu. ft.	0.15 per quarter year per 1000 cu. ft.
Over 500,000 cu. ft.		0.10 per quarter year per 1000 cu. ft.

Minimum charge $1.00 per quarter.

The corresponding charges for premises outside the city limits are: $1.25, $0.38, $0.31, $0.25, $0.19 and $0.13, respectively, with a minimum charge of $1.25 per quarter year.

If the water supply on any premises is not metered by the city, it shall be metered or measured in some way by the Director of Water.

5% discount for prompt payment. 5% penalty for delinquent bills. City, school, county, state or federal property is exempt. However, the Dayton State Hospital for the Insane, The National Military Home for Disabled Soldiers or the Wright Aviation Field (maintained by the U. S. Government) are not exempt.

(8) *Brockton, Mass.*

15¢ per 100 cu. ft. of water consumed per quarter. Part of cost (40%) also paid from a general tax levy.

(9) *Washington Suburban Sanitary District*

Sewerage service paid for by a sewer connection fee ($0.35) plus a general tax (direct property 5¢ per $100 plus 26¢ per front foot) plus a water consumption charge ($0.18 per 1000 gallon).

(10) *Manila, P. I.*

Sewer connection charge plus a meter charge plus a water consumption charge.

(11) *Framington, Mass.*

$0.0875 per 100 cu. ft. of water up to 10,000 cu. ft. and for larger amounts a rate down to 3½¢ per 100 cu. ft. is made. Minimum charge of $2.10. These charges are equivalent to 35% of the water bill.

(12) *Hudson, Mass.*

25¢ per 100 cu. ft. of water consumed, with a 25% discount for prompt payment. Minimum annual charge of $6.00.

(13) *Marlborough, Mass.*

7½¢ per 100 cu. ft. of metered water, with a $4.00 minimum annual charge. In the case of unmetered water supply, a $6.00 minimum annual charge is provided.

(14) *Natick, Mass.*

25¢ per 100 cu. ft. of water, with a $6.00 minimum annual charge. This fund is used both for sewerage and water supply. Equivalent to 100% of the water bill.

(15) *Peabody, Mass.*

$0.0375 per 100 cu. ft. of metered water, equivalent to 25% of the water bill. Industries pay charges according to volume of waste.

(16) *Reading, Mass.*

Semi-annual charge of 30¢ per 100 cu. ft. metered water, with minimum annual charge of $6.00. Equivalent to 86% of water bill.

(17) *Wellesley, Mass.*

Semi-annual charge of 18½ cents per 100 cu. ft. in excess of 2200 cu. ft. used per year. Minimum annual charge of $6.00. These charges represent 100% of the total water bill.

A general summary of Massachusetts cities indicates an average domestic charge of 16.7¢ per 100 cu. ft. of metered water, with an average minimum charge of $4.26.

A summary of 24 Ohio municipalities using sewer rental plans shows that:

(*a*) Average minimum annual charge about $4.00 per sewer connection.

(*b*) Payment usually made quarterly.

(*c*) Of the ordinances,

9 are based upon water consumed.

5 are based upon flat rate single charge per sewer connection.

2 are based according to number of fixtures.

7 are based upon flat rate per connection according to the character of the premises.

(18) *Grand Rapids, Michigan*

Vary from 5¢ per 100 cu. ft. for the first 2200 cu. ft. used each year to 2¢ per 100 cu. ft. for all water used in excess of 200,000 cu. ft.

(19) *North Attleborough, Mass.*

$5 per year minimum charge for 25,000 gallons of water.

B. Percentage Charge on Water Bill.

(1) *Concord, Mass.*

Semi-annual charge based upon 25% of the water bill.

(2) *Framington, Mass.*

Charges based on metered water consumption are equivalent to 35% of the water bill.

(3) *Natick, Mass.*

Water consumption charges equivalent to 100% of the water bill.

(4) *Peabody, Mass.*

Metered water consumption charge equivalent to 25% of water bill.

(5) *Reading, Mass.*

Water consumption charge equivalent to 86% of the water bill.

(6) *Wellesley, Mass.*

Water consumption charges represent 100% of the total water bill.

(7) *Yazoo City, Mississippi*

20% of water bill.

(8) *Thomasville, N. C.*

Service charge 20% of water bill.

(9) *Winston-Salem, N. C.*

10% of water bill.

(10) *Media, Pennsylvania*

40% of water bill.

C. Charges Included with a General Tax Levy.

(1) *Brockton, Mass.*

General tax levy plus 15¢ per 100 cu. ft. of water consumed. The general tax covers about 40% of the cost.

(2) *Washington Suburban Sanitary District*

Sewer connection fee plus a general tax plus a water consumption charge.

(3) *Baltimore, Md.*

Direct tax of 18¢ per $100 plus water consumption charge. If water is un-

metered, charge on flat rate basis averages about $12.00 per year. Otherwise a charge of $2.00 per 1000 cu. ft. for the first 5000 cu. ft. is made.

(4) *Washington Suburban Sanitary District, Md.*

Sewer connection fee ($35) plus a general tax (direct property 5¢ per $100 plus maximum residential tax of 26¢ per front foot) plus a water consumption charge (18¢ per 1000 gallons).

(5) *Anne Arundel Sanitary District, Md.*

Average front foot assessment of 27¢ plus property tax of 5¢ per $100. Flat rate water consumption charge of $15. Where meters are installed a charge of 40¢ per 1000 gallons for the first 10,000 gallons is made. Quarterly installments.

(6) *Cumberland, Md.*

12¢ per linear foot plus $15 sewer connection charge. Water consumption charge: $27.50 on a flat rate basis, or 25¢ per 1000 gallons up to 5000 gallons. Minimum charge $12 in case of metered service.

(7) *Hagerstown, Md,*

Sewer service charge $10 per year. Property tax 26¢ per $100. Sewer house connection charge of $15. Water consumption charge 30¢ per 1000 gallons per month up to 3333 gallons.

(8) *Salisbury, Md.*

General property tax of 34¢ per $100 and a water consumption charge of $15 on a flat rate basis. In case of metered service, a charge of 20¢ per 1000 gallons is made.

(9) *Elkton, Md.*

Property tax of 11.5¢ per $100 and a sewer house connection charge of $10. Flat rate water consumption charge of $21.20 or 25¢ per 1000 gallons up to 5000 gallons and 20¢ per 1000 gallons for the next 5000 gallons, in case of metered service. Quarterly collections.

(10) *Compton, California*

Added tax rate of 32¢ per $100 of assessed valuation.

(11) *New Haven, Connecticut*

$1.75 per front foot on both sides of street.

(12) *Charlotte, N. C.*

3¢ per front foot.

D. Flat Rate, According to Number of Fixtures.

(1) *Columbiana, Ohio*

For unmetered property: minimum of $1.25 per quarter per residence. For factories and shops: for each commode 50¢ per quarter, 50¢ per urinal, 50¢ per lavatory.

(2) *Minerva, Ohio*

Stores, restaurants, offices and mercantile establishments.

Private toilets	$4.00 each per annum
Public toilets	8.00 each per annum
Kitchen sinks	4.00 each per annum
Slop sinks	2.00 each per annum
Churches—each toilet	4.00 per annum

See Secs. E and F for other charges. 10% penalty on delinquent bills.

(3) *Bellefontaine, Ohio*

Stores, restaurants, offices and mercantile establishments.

Private toilets	$3.00 each per year

Public toilets	6.00 each per year
Kitchen sinks	3.00 each per year
Slop sinks	1.50 each per year
Churches—each toilet	1.50 per year

See Secs. A, E and F for other charges.

(4) *Pitman, New Jersey*

Each sink	$2.00 per year	
Each toilet	1.00 per year	
Each bathtub	1.00 per year	
Each laundry tub	0.50 per year	5% penalty and 7% interest
Each washstand or lavatory	1.00 per year	on bills delinquent more
Each urinal	2.00 per year	than one month

See Sec. F for additional charge.

(5) *Delaware, Ohio*

Stores, restaurants, offices and mercantile establishments: (same as for Minerva, Sec. D (2)).

Churches: each toilet $2.00 per annum. 10% penalty on delinquent bills. Industrial wastes may also be charged for.

(6) *Hanover, Pennsylvania*

A charge is made for each of the following fixtures: water closet, bathtub, kitchen sink, wash basin, laundry tubs, urinal, shower bath and cellar drain.

Sewer rentals outside the city are 60% greater than regular charges. Semi-annual basis.

(7) *Ardmore, Pennsylvania*

A charge is made for each of the following: sink, water closet, bathtub, soda fountain, garage drains, etc. There are 20 standard rates with other special ones for offices, theatres, hotels, stores, colleges, laundries, commercial garages ($30 each) and public toilet rooms ($30 each.)

Bills against private dwellings and churches are given a discount of 30%, with a minimum rental of $4. Minimum rental for other buildings, $5.00. 5% discount for prompt payment.

(8) *Lower Merion, Jenkintown, Haverford, Radnor, Abington and Cheltenham Townships in Pennsylvania.*

A charge is made for each of the following fixtures: sink, water closet, basin, shower, bathtub and laundry tubs. Factories, hospitals and colleges are given special rates. Discounts as high as 30% are given in some cases, with an additional 5% for prompt payment.

(9) *Atlantic City, N. J.*

Rates charged by a privately owned company are based on number of fixtures and rooms, and on the square feet of floor space.

(10) *Grand Rapids, Michigan*

Ready-to-serve charge varies from $6 per year for $^5/_8$" to $^3/_4$" meters, to $381 per year for 6 inch meters.

See Sec. A (18) for other charges.

(11) *Moorestown, N. J.*

Private house with 4 fixtures $11 per year.

(12) *Tenafly, N. J.*

$5 per fixture.

E. Charges Based on Number of Persons on Premises.

(1) *Minerva, Ohio*

Factories and shops: each employe

10 persons or less, 75¢ each per annum. $4 minimum charge.
More than 10 and not over 25, 60¢ per annum
More than 25 and not over 50, 45¢ per annum
More than 50 and not over 100, 35¢ per annum
All over 100, 30¢ per annum.

Public schools: 20¢ per annum for each pupil and teacher.

See Sec. D (2) and F (2) for other charges. 10% penalty on delinquent bills.

(2) *Bellefontaine, Ohio*

Factories and shops: each person employed.

10 or less	75¢ each per year
10 to 25	70¢ each per year
25 to 50	60¢ each per year
50 to 100	50¢ each per year
Over 100	40¢ each per year

See Sec. A (3), and F (3) for other charges.

(3) *Delaware, Ohio*

Factories and shops: each employe

10 or less	$1.00 each per annum
More than 10 and not over 25	0.90 each per annum
More than 25 and not over 50	0.80 each per annum
More than 50 and not over 100	0.70 each per annum
All over 100	0.60 each per annum

Colleges: 75¢ per annum for each registered student.

See Sec. F (6) and D (5) for other charges. 10% penalty on delinquent bills. Industrial wastes may also be charged for.

F. Flat Rate Charge for Residences and Business Houses.

(1) *Wrightsville Beach, N. C.*

$5.00 per annum per house.

(2) *Minerva, Ohio*

One family resident (one connection)	$4.00 per annum
Two family resident (one connection)	7.50 per annum
Two family resident (two connections)	8.00 per annum
Four family resident (two connections)	15.00 per annum
Others (for each family)	4.00 per annum

For each additional family on the same connection, $3.75

Hotels: $1.75 per annum for each room with bath.
1.00 per annum for each room without bath.

Rooming houses and fraternities: $4 per annum plus $1.00 for each person renting a room therein.

See Sec. D (2) and E (1) for other charges. A charge for industrial wastes may also be levied. 10% penalty on delinquent bills.

(3) *Bellefontaine, Ohio*

Dwellings: $3 per family per connection per year.

Hotels: each room with bath $1.50 per year.
each room without bath 75¢ per year.

Rooming houses: $3 per year plus $1 per year for each person renting a room.

Hospitals: Mary Ruten Hospital, $50 per year.
Harbert Hospital, $12 per year.
Slaughter houses: $60 per year.
Packing plants: $25 per year.
See Sec. D (3) and E (2) for other charges.

(4) *Pitman, New Jersey*

Each store, residence or apartment $1.25 per year service charge. See Sec. D (4) for additional charges.

(5) *Mason, Michigan*

For premises having unmetered water service.

Single family dwellings	$5.00 per annum
Two family dwellings	9.50 per annum
Each additional family	4.00 per annum

20% discount for prompt payment.

See Sec. A (5) for other charges. (This sewer rental ordinance was repealed shortly after it was passed, due to a political upheaval. It was considered a fair ordinance by the State Board of Health.)

(6) *Delaware, Ohio*

Same basis and rates as are in force at Minerva, Ohio (see Sec. F (2) for dwellings and apartments, hotels, rooming houses, and fraternities).

Hospitals and sanitariums:

Delaware Spring Sanitarium	$100 per annum
Jane M. Case Hospital	60 per annum

10% penalty on delinquent bills. Industrial wastes may also be charged for.

(7) *Athol, Mass.*

Minimum flat rate charge of $3.00 per tenement or block.

(8) *Taunton, Mass.*

Flat rate per tenement or block. Minimum annual charge $2.50.

(9) *Alexander City, Alabama*

$6 per year for each connection.

(10) *Mena, Arkansas*

Charges average $2.50 per house per quarter.

(11) *Ellsworth, Kansas*

$7.20 per year for residences; $10.80 per year for business houses.

(12) *Englewood, N. J.*

$10 minimum per connection.

(13) *Alpine, Texas*

$12 per residence; $24 for business places.

(14) *Haskell, Texas*

$15 per year per residence.

(15) *Pampa, Texas*

$6 per year per residence.

(16) *San Angelo, Texas*

$4.50 per quarter for residences.

APPENDIX C

Bibliography of Sewer Rental Charges and Laws

(1) "A Plan for Meeting Water Supply and Sewerage Costs." By R. B. Morse and Abel Wolman, *Engineering News-Record*, **86**, 944 (1921).

(2) "Rates of Charges for Sewerage Service." By S. A. Greeley, *American Soc. Mun. Improvements*, p. 278 (1926).

(3) "Financing Sewage Treatment by Ohio Sewer Rental Law," *Waterworks*, p. 173, (April, 1928).

(4) "Sewer Charges Authorized in New York State," *Engineering News-Record*, **103,** 10 (July 4, 1929).

(5) "Sewer Rentals Pay for Treatment Plant," *Public Works*, **63,** 21 (March, 1932); also abstracted in *Sewage Works Journal*, **4,** 717–18 (July, 1932).

(6) "Sewer Service at Manila Charged for on Metered Water Consumption Basis," *Engineering News-Record*, **99,** 404 (Sept. 8, 1927).

(7) "Sewer Rentals or Charges for Sewerage Service." By S. A. Greeley, *Mun. Index*, Sec. 8, p. 430 (1932).

(8) "Sewer Rental Plan and Laws," *1st, 2nd, 3rd and 4th Annual Report of Ohio Conference on Sewage Treatment* (1927, 1928, 1929 and 1930). Dept. of Health, Columbus, Ohio.

(9) "Making Sewage Disposal Pay Its Way." By S. F. Wagner, *American City*, **40,** 157 (May, 1929).

(10) "Metropolitan District Plans in Maryland." By A. Wolman, *Pub. Works*, **55,** 242 (August, 1924).

(11) "Sewer Rental Proposed in Connecticut"—Editorial, *Water Works and Sewerage*, p. 397 (November, 1930).

(12) "Financing the Operation of Sewage Disposal Plants." By N. T. Veatch, Jr., *Water Works and Sewerage*, p. 495 (Nov., 1929).

(13) "Financing Sewage Disposal Plants in Ohio," *Public Works*, p. 63 (Jan., 1932).

(14) "Lima, Ohio, Sewage Plant to Be Maintained by Service Charge," *Municipal Sanitation*, pp. 147–68 (April, 1932).

(15) "Schedule of Charges for Sewage Works on a Rational Basis," *Engineering News-Record*, **108,** 407 (March 17, 1932).

(16) "Methods of Financing Sewerage Systems." By H. P. Eddy, *Engineering News-Record*, **105,** 727 (Nov. 6, 1930).

(17) "Sewer Rentals in Pennsylvania." By G. M. Olewiler, SEWAGE WORKS JOURNAL, **4,** 300 (March, 1932).

(18) "Financing Sewage Disposal." By H. R. Green, *Ibid.*, **4,** 288 (March, 1932).

(19) "Operation of Sewer Rental Laws." By F. W. Jones, SEWAGE WORKS JOURNAL, **3,** 96–101 (January, 1931).

(20) "Sewer Rentals." By H. S. Crocker, *Ibid.*, **3,** 102 (January, 1931).

(21) "Rate Schedule of Atlantic City Sewer Co." By C. Wigley, *Engineering News-Record*, **107,** 410 (Sept. 10, 1931).

(22) "Charges for Sewerage Service." By F. A. Marston, *Am. Soc. Mun. Improvements*, **35,** 377 (1929–30).

(23) "Service Fees and Annual Charges for Sewer Connections." By S. A. Greeley, *Am. Soc. Mun. Imp.*, **37,** 356 (1931–32) and F. A. Marston, *Ibid.*, **37,** 360 (1931–32).

(24) "Financing the Operation and Maintenance of Sewage Treatment Plants." By E. Boyce, *Municipal News*, **76,** 305 (July, 1929).

(25) "Charges for Sewerage Service." By F. A. Marston, *Public Works*, **60,** 478 (Dec., 1929).

(26) "Sewer Rentals Result in Better Plant Operation," *Municipal Sanitation*, **1,** 631 (November, 1930).

(27) "Financing Sewage Treatment," The Round Table, *Municipal Sanitation*, **1,** 461 (Aug., 1930).

(28) "Financing Sewer Maintenance." By L. B. Reynolds, *Journal California Sewage Works Association* (1928).

(29) "Sewage Treatment in Wisconsin." By L. F. Warrick, SEWAGE WORKS JOURNAL, **1**, 481 (July, 1929).

(30) "Statistics on the Collection and Treatment of Sewage and Trade Wastes," *Mun. Index*, Sec. 10, p. 613 (1931).

(31) "Relation Between the Legal and Economic Limitations to Engineering in a Metropolitan Sanitary District"—A thesis by A. L. Nowicki, University of Minnesota, Chap. V, pp. 101–51 (June, 1932).

(32) "Annual Charges for Sewerage Service." By F. A. Marston, *Annual Conference of New York Officials* (June, 1930).

(33) "Financing, Rental and Amortization of Private Sewerage System at Troy, Pa." By H. W. Taylor, *Am. Soc. Mun. Imp.*, p. 290 (1926).

(34) "Financing the Baltimore Sewerage System." By Milton Ruark and C. E. Keefer, *Eng. News-Record*, p. 724 (May 5, 1927).

(35) "Fourteenth Annual Meeting, N. J. Sewage Works Association," *Proceedings* (March 22–23, 1929).

(36) Annual Reports of the Sewer Commissioners and City Engineer, Brockton, Mass.

(37) Act 320 of the Public Acts of 1927 of the State of Michigan.

(38) Public Utility Reports, Pennsylvania Public Service Commission, 1928.

(39) General Laws of Massachusetts, Chap. 83, Sec. 16, 1892.

(40) Laws of New York (1929), Chap. 225 and 678, Sec. 279, Article XI.

(41) Laws of Pennsylvania, Sec. 2170–73, Ordinance for Annual Rental.

(42) Laws of Michigan, Act 160, Amended in 1929.

(43) Laws of Iowa, Chap. 157, Senate File 327, 1921. Sewer Rentals.

(44) Laws of Ohio, Sec. 3891, 1929. Sewer Rental Law.

(45) Laws of Wisconsin, Sec. (66.06) (22), 1931. Sewer Rental Law.

(46) Connecticut, House Bill No. 696, 1931.

(47) Laws of New Jersey, Chap. 152, Article 21, P. G. of 1917.

(48) North Carolina, Chap. 100, Public Laws of North Carolina, Session of 1927, Providing for Creation of Sanitary Districts.

(49) Laws of Maryland, Chap. 641, Sec. 3480, 1927.

(50) Laws of Kansas, Chap. 136, 1929.

(51) Laws of Indiana-Sewer Service Charge and Revenue Bond Act. Sections 14 and 15. Special Session 1932.

(52) "Sewer Rental in Ohio." By F. H. Waring, Paper read before the 19th Annual Convention of the Minn. League of Municipalities at Red Wing, Minn., June 9, 1932.

The Rockford, Illinois, Sewage Treatment Works. Dedicatory Address*

BY FRED E. CARPENTER

Former Judge, Winnebago County, Illinois

Editor's Note.—This address by Judge Carpenter, in dedication of the Rockford Sewage Treatment Works, is quite different from the usual technical articles that appear in THIS JOURNAL, *but it may appeal to the readers as it appealed to the Editor, in that it brings a loftier conception of the purpose of sewage treatment than one gains from the succession of technical and scientific articles with which this publication is usually filled. The view-point of the layman, of the Izaak Waltonian, of the nature lover is seldom presented in the technical press. In Judge Carpenter's address, however, we can catch the nobility of purpose that inspires certain public spirited men to inaugurate and carry through expensive sewage treatment projects.*

The public servant who today cares for the taxpayers' money as though it were his own is emblazoned in a sort of glory, which I think will last for a good many years. The trustees of the Rockford Sanitary District have lived up one hundred per cent to that high ideal, which ought to be set for every official who spends the taxpayers' money.

As a citizen and taxpayer of this community, I realize that three million dollars is quite a sum to spend for any kind of improvement to be dedicated in these troublous times. In order to say very much about this achievement, it is necessary for me to discuss further what it is, what it has done and what its object is, because most of the citizens of this community can see only these buildings, which do not mean very much to a person not trained in the art of sanitary service; most of the money was spent under the ground.

Let me trace somewhat the history of this community, for the benefit largely of strangers—I suppose Rockford people know all about it. Our state was admitted to the Union in 1818, but at that time the entire state of Illinois, as far as people were concerned, was in the southern and central part of the country. This was Indian country, and it was not clear of the Indians until about a hundred years ago.

After the close of the Black Hawk War, there were many reports, sent through the east, about the beauty and fertility of the Rock River Valley, and people began to come into this valley. My own maternal ancestors struck the Rock River in a covered wagon, traveled up this stream, not over eighty rods from where we are now gathered, and settled out here in 1835.

There were just two houses in Rockford at that time; soon more and more covered wagons came into this community. My ancestors, and most

* *Presented before the Joint Meeting of the Illinois Association of Sanitary Districts and Central States Sewage Works Association, Rockford, Illinois, May 13, 1932.*

of the people, were looking for homes in fertile land, cities were established, our city was established and that inevitable thing which occurs with civilization and settlement occurred here. People had to have some sort of sewage relief, so they had simple sewer connections with Rock River.

Just think of what my ancestors and those early settlers saw when they came into this country! They tell me this stream ran crystal clear; one could see to the bottom, see the fish in the river; all the tributaries to the river had pure water in them. Men could drink out of any running stream. But soon, for purposes of protection or gain, people gathered in these cities and in this city, built sewer connections to the river for the disposal of human waste, and afterward the waste of the factories, and soon the stream began to run filth. Then we built a dam in the middle of the city, and we built eighty-five or ninety private and public sewers into the river, north of the dam. We accumulated a cesspool, and then we proceeded to live around that cesspool. That could not go on forever.

A modest amount of sewage may be carried away by the stream, but not so much as this growing manufacturing town demanded. This city is probably the second manufacturing city in the state; it is the third in point of population. In the brief space of a hundred years, the beautiful scene that nature presented, this valley with the oak and deciduous trees crowning the hillsides, the pure stream flowing along the valley, great prairies interspersed along either side of the river, inviting the home seeker—all these scenes have been changed by the virtue of our own occupation.

This valley produced homes and livelihood for all who came here, wealth for many; but it also brought other things detrimental to the health of human beings. I wonder how many of you have in your boyhood ridden down this river in a canoe, or in your manhood or womanhood taken automobile trips from Watertown, Wisconsin, on down the valley to Rock Island.

Nicholas Murray Butler, the President of Columbia University, says that in this space of earth running from Madison, Wisconsin, southwesterly to Rock Island, Illinois, in a general way following the Rock River and its tributaries, there is gathered the best example of a true American civilization that we have in the United States.

Our early settlers were from New England, New York, our so-called foreign settlement was from England, Germany, Scandinavia, including Denmark, Sweden and Norway. We are all Nordics, and all determined, with a fierce energy, to establish homes, and good homes, and no part of our country has seen the establishment so quickly of homes, churches, of school houses and roads, as this community.

Another foremost authority says that the four most beautiful valleys in this country are the Hudson, the Columbia, the Tennessee and the Rock River.

To go down this valley at any season of the year and see the natural beauties, the vistas that are open to the eye either by water or land, is most refreshing and well worth the expense and energy of the trip. Watertown, Jefferson, Janesville, Beloit and Fort Atkinson in Wisconsin, Rockford, Oregon, Dixon, Sterling and Rock Island in this state—why, they are all like pearls, strung on a silver strand, manufacturing cities, in whose borders can be found reasonable output for human ambition, surrounded by agricultural country capable of feeding the world.

Now, man, in coming into this halcyon and rather idealistic natural condition, brought the penalties and pains of progress. We poisoned the soil. We corrupted the streams. We lived, as I said, around this cesspool. Modern science, modern education, modern experience, tells us that a situation like that cannot be, and a great wave has come over Illinois which is designed to remove that poison and take that filth out of our streams. Without lessening our appreciation one bit for educational institutions or institutions that minister to the spirit, religious institutions and all that, we must first have pure air, pure water and sanitary surroundings before these other things avail us anything.

Our state law has always forbidden the dumping of sewage into running streams, and our Chancery Courts have always held that the upper proprietor cannot throw refuse into a stream to the detriment of the man who lives down stream.

If there are any of you here from Jacksonville, Illinois, you will recall the famous lawsuit that was held down there in the Circuit Court, wherein the farmers along the Mauvisterre River enjoined the city of Jacksonville from dumping its sewage into the Mauvisterre, creating smells and nuisances down stream, and poisoning the waters which the farmer's stock used.

The Circuit Judge at Jacksonville gave the City five years to put its house in order. We had something of the same thing here. Farmers down stream filed a bill for an injunction against the City of Rockford for corrupting this stream and throwing its filth down the valley. The Izaak Walton League, under splendid leadership and with enthusiastic and altruistic sentiments, wished to have the stream clear, so that fish could live, so that it would be healthy and desirable for human beings. Those two forces, together, created the sentiment back of a special election, which we held, and the election carried for this improvement.

The bond issue carried, and today we are at the fruition of the efforts of many, many thousands of people, who desired to see this thing happen. To my mind, this is the most important event which Rockford has ever experienced.

In the years to come we will look back on this day as one of those events which are more than milestones of human progress for our city. You who know the law, know that there has been no way of assessing property

outside of the corporation of Rockford, or outside of any city corporation, to compel the owners of property to put in sewage disposal plants. Now the way is clear. This Sanitary District includes not only the city of Rockford, but much outlying land, and in that outlying land the poor, the ambitious, the working man has his home. He would like to have sewer facilities, but could not have it under the old law; but now he can petition this Board and compel his neighbor, who may be holding land for gain, to pay the expense of a proper sanitary disposal system and to empty the sewage into this plant.

We were in danger of having our city surrounded by a potential typhoid fever belt. To those of us that live here, may I suggest that the population of Love's Park, with their wells and cesspools right next to each other, and the population of this part of our city outside the city limits, were a distinct menace to the good health of our city. Now that is removed. This plant is built. The intercepting sewer took all this poison and waste and carried it down here where it is treated and passed on into the stream as a harmless fluid.

Now as a former County Judge, who appointed the gentlemen who have carried out this work, may I publicly thank these Trustees for what they have done, and done honestly and well? May I thank Dr. Gunderson, our Health Officer, who has been most helpful in carrying this thing through, in getting the original ideas and explaining to the people in the preliminary campaign the great benefit that would come to the health of this city by the operation of this plant.

To the members of the Izaak Walton League for their enthusiasm to clear up this stream; to the good citizens; the common man who worked for and voted for this thing which meant no immediate gain to him, but meant in the opinion of all scientific men great happiness and better health conditions for all the citizens of Rockford, to all of you I extend my thanks.

And so far as it is possible for me to do, may I dedicate this plant to the men and women and children who come after us, to those unknown persons to you and me, who will be the inheritors of what we have done, be it good or bad. May I dedicate this for the good health of the community. May I dedicate it and say that it is the one big altruistic thing that the people of this community have done in my lifetime and in my experience.

We raise money for corporations to make money. We see those corporations prosper or they fade like snow on the desert's dusty face; but there is no object in this plant of any individual making money, nor should there be. The only object is that we may secure for those that come after us that vital, that priceless thing, good health; that we may secure this city from the ravages of water-borne diseases; that the poor and the rich alike may feel that they are reasonably free from typhoid fever and allied diseases; and that we may gratify our higher nature by seeing our beauti-

ful river again restored to that which it was when our ancestors came into this country. A running stream is a beautiful thing. Our Nordic ancestors believed that a stream had a spirit in it. They believed in the Gods of the stream. They could see in the running waters a living spiritual entity; may this stream be so clear and so beautiful that in the years to come it will be restored to its pristine glory and beauty and cleanliness.

Man changes, officials change from time to time; usually there is an improvement; one man goes out of office, another comes in; a change for the better is very often the result, and no doubt each succeeding Board of Trustees will conceive of something which would not have been thought of by their predecessors to make this a desirable and successful plant. For my part, I am going to ask one thing, as a citizen of this community. I remember that when the lawsuit was tried in County Court, involving the right to take possession of this property, there was much evidence offered that this would be a contamination for this neighborhood. For my part, I feel sure that those fears were unfounded, but I hope that this succeeding Board and Boards coming in after it will so beautify this spot that it will be a place of frequent resort as a park for people of this community. I make the prediction that it will so appeal to future Boards that this will be the most interesting, most frequented park in our city, because right here is a vital thing, a scientific thing, being carried on for your benefit and for mine and those who come after us.

There will be grass and flowers and singing birds, tired men and tired women and children will recreate and refresh themselves on this spot, and you will know that way back, way back in 1932, they dedicated this institution with its wonderful scientific paraphernalia for the benefit of the common man.

Institutional Sewage and Sewage Flow Characteristics*

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During the course of routine supervision over the operation of New Jersey State institutional water and sewage plants, the writers have collected considerable data on the characteristics of raw sewages and sewage flows from institutions of different types.

Since little information has been published on this subject, these data are presented to show the flow characteristics of institutional sewage with respect to their effect on the design and operation of institutional sewage treatment plants.

The results herewith presented will also show that methods very often used in estimating sewage flows from municipalities, especially the smaller towns, are not applicable either to the estimation of strength of sewages or quantity of sewage flows from institutions. Distinctive characteristics of institutional sewage flows place them in an individual classification.

Sewage Flow Characteristics

Fundamentally, all institutional sewage flows have two common characteristics. These are high peak discharges and large per capita flows. The high flow-rates and wide fluctuations are due to the routine habits usually followed at all institutions. The high per capita flow is due, first, to the necessary use of large quantities of water in the treatment of certain types of patients or inmates and, second, to uncontrollable waste of water by irresponsible patients.

These general characteristics of institutional flows also vary among institutions, depending on type of institution and topographical situation.

The extent by which the total daily quantities of flow vary at different New Jersey institutions is shown in Table I, Column 5.

Generally speaking, largest flows were found at the tuberculosis and insane hospitals, with flows ranging between 194 and 266 gallons per capita. The flow of 160 gal. per capita at Hillsdale insane hospital is somewhat lower than the flow from the similar type of institution at Greystone Park due to the absence of continuous baths which are used at Greystone Park. When these baths are added at Hillsdale the flow will be increased to about the same amount as that at Greystone Park.

The second largest flows were obtained from the epileptic colony (170 gal. per capita).

The lowest flows were found at boys' reformatories, which ranged from

* *Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Dept. Sewage Research.*

TABLE I

SEWAGE FLOW CHARACTERISTICS OF DIFFERENT TYPE OF INSTITUTIONS

				Per Capita Flows in Gallons (On Basis of Inmate Population)			
Institution	Type of Institution	No. of Patients	No. of Employees	Avg. Daily	Max. Day Avg.	Max. Rate	Min. Rate	Required per Capita Designing Rate
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Glen Gardner	Tuberculosis Sant.	411	197	266	291	1270	89	630
Jamesburg	Boys Correctional	650	150	150	180	494	20	260
Greystone Park	Insane	4068	930	197	270	512	65	330
Woodbine	Feeble Minded	419	104	194	216	640	28	358
Skillman	Epileptic	1240	225	170	207	256	69	205
Hillsdale*	Insane	1040	...	160*	170	456	20	280
Annandale*	Boys Reformatory	300	57	99*	113	640	15	170

*See Text

99 to 150 gal. per capita. The exceptionally low flow at Annandale Reformatory is due to somewhat abnormal conditions. The lack of excess supply of water at the institution at the time these measurements were taken required the greatest possible conservation of water around the institution.

As previously mentioned, the extent of variation of rates of flows at different institutions is affected by the topographical and geographical situation of the institution. In detail, the factors are: (1) distance between contributing buildings, (2) distance between point of concentration in the collecting system and sewage plant and (3) grade of sewer line between point of concentration and sewage plant.

An example of the extent of the effect of topographical features can be seen in Figure 1. While the average per capita flows represented by the curves were approximately the same at both institutions the ratio of maximum flow rate to average rate for Greystone Park is 2.2, while that for Skillman is only 1.5. Designing rate to average rate is 1.7 and 1.2, respectively.

The maximum extent to which these ratios were found to diverge under dissimilar collections and topographical conditions can be seen by further comparison of Glen Gardner and Skillman.

The institution at Glen Gardner lies on the slope of a steep hill and the buildings are closely located. The average sewer grade between the buildings and sewage plant is about 10.9 per cent. Under these conditions the ratio of maximum rate to average flow is 4.8. The ratio of designing rate to average rate is 2.4.

The institution at Skillman is located under conditions very different from those at Glen Gardner. The grade of the sewer line between institution and plant at Skillman is very small, amounting to only 0.28 per cent. In addition, the buildings are scattered over a large area and no

particular point of concentration is available within a short distance of all the buildings such as exists at Glen Gardner. As a consequence the ratio of maximum rate to average daily flow at Skillman is only 1.5 and the ratio of designing rate to average flow only 1.2.

If we still further compare these same ratios of institutional flows under similar collecting systems and approximately equal topographical conditions and grade lines we find that the ratios are fairly equal. The following tabulation show ratios of those institutions lying under approximately similar conditions.

	Avg. per Capita Flow	Ratio of Maximum Rate to Avg. Rate	Ratio of Designing Rate to Avg. Rate
Jamesburg	150	3.3	1.8
Greystone Park	197	2.6	1.7
Woodbine	194	3.3	1.8
Hillsdale	160	2.8	1.7
Average		3.0	1.75

These ratios have been calculated from the averages shown in Table I.

The foregoing data show the inadvisability of designing any institutional sewage plant on any other basis than accurately measured sewage flows or at least from estimation by carefully comparing with another institution of the same type, with similar collecting systems and points of concentration, and under similar topographical conditions. The characteristics of institutional flows require even more careful study for accurate flow estimation than do strictly domestic sewage flows for municipalities. The reason is due to a much greater divergence in sewage flows from different types of institutions and in the pronounced effect of the topographical situation. This latter factor is especially influential at institutions by virtue of the routine habits which cause the sewage to be discharged into the sewer in periodic and short intervals. As an example even a sharp grade sewer line to the plant would not cause excessive flow rates provided the sewage were more or less uniformly introduced in the sewer line throughout the day. But when the major sewage contributing period is only 14 hours out of the 24-hour period, and upon this is superimposed large instantaneous quantities of discharges from laundries, bathing, washing and use of commodes in short intervals of time, a sharp grade sewer line will give excessive rates of flows that will materially affect the functioning of the sewage plant.

These factors, namely, concentration in the collection system and grade of sewer line to the sewer plant, are probably of the greatest importance in affecting the plant operation and design. Even under the most ideal conditions of collection, with wide distribution of building outlets to the collection system and minimum sewer line grades, the sewage flow from

institutions is much larger per capita than ordinarily encountered in municipalities and will generally require a plant almost twice as large as from an equivalent number of municipal population. An example of this is Skillman, where the average rate of sewage flow is 170 gal. per capita and designing rate is 205 gal. per capita. However, under other conditions less favorable, such as a single point of concentration of sewage and sharp sewer line grades to sewage plant, the required designing rate may require

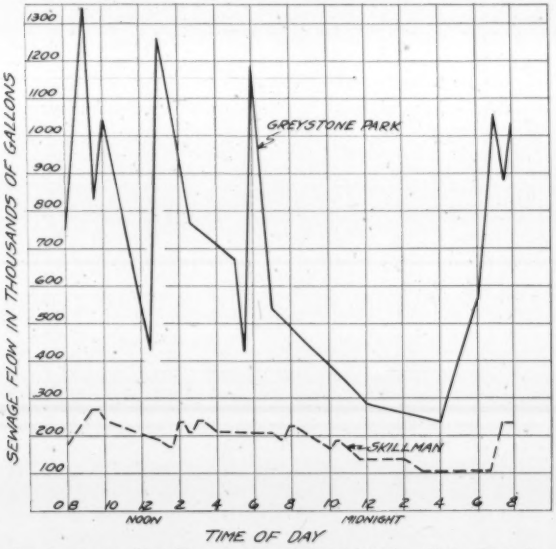

FIG. 1.—Sewage Flow Characteristics of Two Institutions Under Dissimilar Topographical and Collection Features.

a plant or at least certain units of the plant 5 or 6 times as large as from equivalent municipal population. An example of this is Glen Gardner, under topographical conditions previously described, where the average rate is 266 gal. per capita but where the designing rate is 630 gal. per capita. Under other conditions, which are those more ordinarily encountered, the designing rates vary between 260 and 350 gal. per capita, which represent figures at least $1^1/_2$ to 2 times as large as from an equivalent municipal population.

Composition of Raw Sewage

It is a more or less common impression that institutional wastes fall in the classification of weak sewages, due to the absence of any industrial wastes, a large dilution factor and freshness of sewage.

In the course of supervision of these institutional plants, analyses have been made on composite samples of the raw sewages from all the institutions mentioned under the section on sewage flows. The analyses of these

TABLE II

ANALYSES OF RAW SEWAGE FROM DIFFERENT INSTITUTIONS

Determination	Annandale (Boys Reformatory)	Jamesburg (Boys Correctional)	Skillman (Epileptic)	Hillsdale (Insane)	Greystone Park (Insane)	Glen Gardner (Tuberculosis)
5-Day B. O. D., p. p. m.	430	450	300	235	180	172
Total Solids, p. p. m.	1144	325	620	580	334	390
Suspended Solids, p. p. m.	627	326	322	156	84	140
% Ash	17	19	18	...	18	...
Settleable Solids, cc. per l.	11	4	4	4	5	5
pH Value	8.3	8.1	7.4	7.8	7.1	7.0
Ether Soluble, p. p. m.	200	145	54	48	46	50
Total Acidity, p. p. m.	20	0	0	0	15	22
Total Alkalinity, p. p. m.	195	150	100	130	95	154
Chlorides, p. p. m.	48	55	37	21	30	40
Dissolved Oxygen, p. p. m.	2.0	0.5	0	1.5	0	2.2

TABLE III

INMATE PER CAPITA QUANTITIES IN RAW SEWAGE FROM DIFFERENT INSTITUTIONS

	Grams per day				Liters per Day
	B. O. D. (20-Day)	Suspended Solids Total	Volatile	Ether-Soluble	Settleable Solids (1½ Hr. Settling)
Annandale	241	238	197	75	4.2
Jamesburg	256	248	202	82	2.4
Skillman	286	207	170	35	2.6
Hillsdale	215	91	75	29	2.4
Greystone Park	208	70	58	38	4.2
Glen Gardner	268	140	115	50	5.0
Average	245				

TABLE IV

COMPOSITION OF FRESH SLUDGE FROM DIFFERENT INSTITUTIONS

Institutions	Dry Solids, %	Ash, %	Ether Soluble, %	Organic Nitrogen, %
Annandale (Fresh Solids)	4.33	22.3	27.6	2.43
Hillsdale (Fresh Solids-Activated Sludge Mixture)	3.8	24.4	18.0	4.12
Activated Sludge	1.1	23.0	17.9	6.6
Jamesburg (Fresh Solids)	4.4	24.0	20.0	1.95

samples are shown in Table II. In Table III quantities are given in grams per capita daily and Table IV shows analyses of fresh sludges taken from the primary settling tanks and sludge from the activated-sludge process. The sludges shown in Table IV represent about the maximum and minimum range of values encountered at the institution.

Discussion

Using the 5-day biochemical oxygen demand as an index of the sewage strength, Table II shows that the institutional sewages as they enter the plant vary considerably in strength and usually much more than expected in fresh domestic sewages. The minimum B. O. D. of 172 p. p. m. found at Glen Gardner is close to the average B. O. D. of fresh domestic sewages. The maximum B. O. D. at Annandale was over $2^1/_2$ times as much or 450 p. p. m. Three of the six institutional sewages had a B. O. D. between 300 and 430 p. p. m. On this basis it is apparent that strong institutional sewages entering the plant are as common as weaker sewages. If the dilution factor is taken into consideration and correction factors are applied for this dilution by calculating on the basis of 100 gal. per capita flow, it will be seen that strong sewages from institutions are the rule, rather than the exception. The 5-day B. O. D. adjusted on this basis is:

	B. O. D. on Basis of 100 Gallons per Capita Flow
Glen Gardner	455
Jamesburg	660
Greystone Park	354
Skillman	510
Hillsdale	400
Annandale	430
Average	468

The average figure for the 5-day B. O. D. of domestic sewage with 100 gallons per capita flow lies between 150 and 200 p. p. m. Accordingly these institutional sewages on the same per capita flow basis are from 2 to 3 times as strong as the average domestic sewages.

This same relation can be followed in Table III where values for daily oxygen demand, suspended solids, both total and volatile, and ether-soluble matter are shown in grams per capita.

The ether-soluble substances in institutional sewages are generally higher than in domestic sewages and in some cases are present in large amount, as shown by the Annandale results. These ether-soluble materials are due to kitchen, soap and laundry wastes. The grease content, when as high as that at Annandale (200 p. p. m.) has been found to be troublesome in the high calcium water used at the institution. The hardness of this water precipitates the grease to such an extent that large quantities of grease balls form on the tank surface and lodge in the sprinkler system. Considerable difficulty has also been encountered at this institution in placing the digesting sludge in proper condition. Much larger amounts of lime have been needed than at other institutions.

Scum formation has been especially troublesome. It might be concluded

from this experience that the high grease content of the raw sewage was responsible for the difficulty in the digestion tanks. Analyses of sludges (in Tabe IV) show that although the grease in the raw sewage at both Annandale and Jamesburg was high, the sludges settled in the primary tank were similar in composition to sludges from domestic sewages. Hence it appears that the burden of high grease and soap content in institutional sewages would be borne by the oxidation devices subsequent to the primary settling units, rather than the digestion units.

Solids content and ash in the institutional sludges were also very similar to the solids and ash contents of sludges from domestic sewages. The ratio of carbonaceous to nitrogenous material, however, is somewhat higher than for sludges from domestic sewages. This did not apply to the activated sludge.

All of the institutional sewages are comparatively fresh as they reach the plant and in most instances carry a small amount of dissolved oxygen.

It is noticeable that the average pH values of all sewages were above neutral and in some cases unusually high. It has been found that the pH value will vary during the day between 6.8 and 9.0. The value depends on the concentrations of soap and laundry wastes in the sewage at the time of sampling. The institutions at Annandale and Jamesburg have a higher average pH due to the smaller per capita dilution factors.

Per capita quantities of total suspended solids ranged from one to three times as high as usually encountered in domestic sewages (see Table III). The volatile content averaged about 82 per cent.

The foregoing characteristics observed in the composition of institutional raw sewages and fresh sludges show certain fundamental properties, which remain more or less constant for all institutions, and other properties which differ quite materially with type of institution. The 20-day oxygen demand in grams per capita per day averages 245 for all institutions studied, with a maximum deviation of only 15 per cent from this figure for any one institution. Suspended materials, both settleable and non-settleable are higher per capita than for strictly domestic figures, but vary quite considerably for different institutions. Volatile matter follows closely the suspended solids content. Grease content varies to quite an extent at different institutions and while very high in some cases, in other cases is as low as that in domestic sewages. The percentage solids, ash and grease contents in fresh sludges are approximately the same as those of average domestic sludges.

The effect of these raw sewage characteristics on the plant design and operation are quite apparent. Oxidation, digestion and sludge drying units must be made much larger than for an equivalent municipal population. When in addition to these raw sewage characteristics the higher per capita flow rates are considered, it is apparent that the entire plant must be larger than a municipal plant for equal population. Also from these

studies on raw sewage characteristics it appears that general estimation of proper capacities for digestion units, sludge drying beds and oxidation units are equally as difficult as the estimation of proper capacities for settling units which are affected by the high flow rates. Here again, in light of the uncertain raw sewage characteristics, the importance of analyses of raw sewage is apparent before plant design can be safely undertaken. If such an analysis cannot be made, the second alternative is estimation by careful comparison with the raw sewage from existing institutions of similar type.

Summary

The results of studies on characteristics of institutional sewage flows and raw sewage composition are given with reference to the effect of these factors on plant design and operation.

Average daily flows varied from 99 to 266 g. p. c. and showed some correlation with type of institution. The ratio of maximum to average rate of flow did not show such correlation but depended on topographical situation, sewer line grades and arrangement of collecting system with respect to sewage plant. The lowest ratio of maximum to average rate of flow was 1.5. The highest was 4.8. Designing rates to average rate also show similar deviations.

Studies on raw sewage show that, contrary to a general impression, institutional sewages were in all cases from 2 to 3 times as strong as strictly domestic sewages. The average 5-day B. O. D. on the basis of 100 gallons per capita flow was 472 p. p. m. Most other sewage constituents were correspondingly higher. Per capita oxygen demand (20-day) varied from 208 to 286 grams per day. Suspended solids both settleable and non-settleable were generally higher than in domestic sewage but varied quite considerably among the institutions. Grease content of raw sewage in some cases was very high. Sludges were in practically all cases very similar to domestic sludges.

The combined influence of higher flow rates and stronger sewages, which vary with different types of institutions and their topographical layout, show the advisability of careful study before deciding upon the design of institutional treatment plants. If the flow cannot be measured, or the sewage analyzed, estimation should be made by careful comparison with an existing institution of similar type and under similar topographical conditions and sewer collection features. If neither of these methods are available, very liberal designing factors should be employed.

Sludge Operations at the Baltimore Sewage Works*

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The Baltimore sewage treatment works, situated at Colgate, Maryland, eight miles from the center of Baltimore, treats sewage from a separate sewer system and serves a population of 750,000. From the inception of the plant in 1911, gradual changes both in treatment and design have resulted in great improvements in the operation of practically every unit. The treatment consists of plain sedimentation and trickling filters, with separate sludge digestion and sludge drying beds.

Description of Works

There are four sedimentation tanks, 403 feet by 103 feet, divided into two compartments, $10^1/_2$ and $13^1/_2$ feet deep, respectively, by a concrete or baffle wall approximately 100 feet from the influent end. Two pump wells, equipped with centrifugal pumps, are situated, one between tanks Nos. 1 and 2, and the other between Nos. 3 and 4. Each pump is available for cleaning two tanks.

While the number of digestion tanks totals 49, all but ten are small and do not serve to treat any appreciable quantity of the digested sludge produced. Of the small tanks, 16 are circular, having a capacity of 20,000 cu. ft. each, and 23 Imhoff tanks, radial flow type, are now utilized for sludge digestion, with a capacity of 16,000 cu. ft. each. In this article only the ten large square tanks will be discussed. Each of these is approximately ten times as large as the circular tanks and holds 200,000 cu. ft. A series of top, middle and bottom valves is available at each corner of the tank. Six of the ten tanks have baffle walls, which cause the sludge to follow a winding course from the point of entry to the point of release at the opposite end. A pumping station, located in the digestion tank area and equipped with two 8-in. centrifugal pumps, facilitates the pumping of supernatant liquor and sludge.

Twelve sludge-drying beds, each containing 20 compartments, cover an area of 13 acres (0.67 sq. ft. per capita). A compartment measures 20 ft. by 100 ft. and is filled with an average of 12 in. of gravel and a topping of 4 in. of washed sand. Sludge dump cars of 1 cu. yd. capacity and gasoline locomotives are used to transport the sludge to a trestle where it is loaded on trucks.

* *Presented before the Sixth Annual Conference of the Pennsylvania Sewage Works Association, State College, June 22, 1932.*

Method of Operation

Rising solids forming scum in the first compartment of the sedimentation tanks are trapped by the curtain wall, thus reducing the quantity in the second or large end. A heavy accumulation of scum, when tanks are in service too long, is reflected in a poor effluent, especially when strong westerly winds prevail; solids being forced down and carried into the effluent channel through the ports several feet below the flow line. A tank remains in service about 4 or 5 days or as fast as cleanings can be completed. Frequent cleaning has resulted in odor reduction and the elimination of myriads of flies.

The first operation of cleaning is dewatering. This is accomplished by allowing the water to flow into the empty tank, last cleaned, by what is called an equalizing pipe line, with a saving of 4 or 5 hr. pumping. The remaining water is pumped into the influent end of a tank in service. When it is detected that sludge is being pumped, valves are set to divert it to the digestion tanks. At this point the scum has settled into the bottom sludge. To facilitate the pumping operation, settled tank effluent is added to the sludge through a $2^1/_2$-inch hose, raising the moisture content to 94 or 95 per cent. If the sludge is much thicker, the pumps occasionally fail to pump the material due to the long distance to the digestion tanks with the attendant increase in head.

The primary settling tank sludge is pumped through 12-in. pipe lines to the square digestion tanks, entering at the northwest corner of the tanks through the bottom and middle valves. Pressure due to pumping requires two valves to be opened, otherwise sludge fills the well and overflows the walls. Odors characteristic of raw sludge are eliminated by the above procedure. In order to make room for the additions of primary settling tank sludge, when digestion tanks become full, supernatant liquor and sludge, too dilute for release to drying beds, are drawn from the middle valve to the pumping station and thence to the influent end of the sedimentation tanks. Sometimes this liquid is too dirty to put through the primary settling tanks and to low in solids for release to drying beds, in which case it is pumped to a sludge lagoon.

Sludge is released to the drying beds from the bottom valves of the digestion tanks at either of the corners farthest removed from the point of entry, the northeast and southeast, depending upon the position of the beds to be filled. Six of the 12 drying beds are some distance from the digestion tanks and to fill these beds the sludge flows to the pumping station nearby and is pumped to the beds. Removal from the sand bed requires that the sludge be removed along the center of the bed so industrial track may be laid to accommodate a train of dump cars. Where beds appear to be clogged, removal of sludge along the center aids ma-

terially in shortening the drying time. The cars are loaded by hand, and then dumped at the sludge trestle, as mentioned previously.

Sludge Characteristics and Data

Primary Settling Tanks.—Baltimore sewage has approximately 225 p. p. m. suspended solids, 75 to 80 per cent of which are removed by sedimentation, and a pH of 6.9. A series of pH tests on fresh solids collected in the primary settling tanks revealed a drop to 5.1 in 24 hours. Sludge pumped to the digestion tanks has a pH ranging from 4.8 to 5.2; moisture content, before dilution, of 82 to 84 per cent; volatile matter, 76 to 78 per cent; and grease 20 to 50 per cent, varying according to changes in type of sewage and location in the tank. Samples are collected at 15-minute intervals from a valve on the sludge pipe line, and composited for each 8-hr. shift. From the digestion tank measurements, together with the moisture determined on the above-mentioned samples, the quantity of raw sludge treated is obtained. The amount approximates 8 cu. yd. per million gallons of sewage (on a 90 per cent moisture basis) or about 0.25 cu. yd. per capita per year.

Digestion Tanks.—The condition of sludge in the square digestion tanks during past years is of interest. Until 1925, as outlined by Keefer ("Experience with Sludge Digestion at the Baltimore Sewage Works," 1925 *Convention Proceedings*, American Society for Municipal Improvements), the dry scum on the tanks varied from several inches to several feet in depth. In the fall of that year one of the tanks developed a gassing activity over the entire surface. This gassing was not of the foaming type generally indicative of sludge not so well digested. It was decided to seed another tank with half of this sludge and allow it to stand over winter, discontinuing additions of raw sludge. Unfortunately, pH records and specific laboratory data were not available on the sludge in these tanks prior to this operation. During 1926 gassing continued, and gradually, by seeding, all tanks were converted to a gassing state in 1929. Dry scum exists on the surface only at times in winter, and when an insufficient quantity of raw sludge is added in summer. It was found that a transference of at least 50,000 cu. ft. of seeded sludge (25 per cent) was necessary to promote gas action. Operators now add one foot in depth of raw sludge to each tank in order, equivalent to 10,000 cu. ft. About four days elapse before the operation is repeated. Owing to the impracticability of determining the quantity of solids in the tanks at all times when operators are ready to make additions, they have been instructed to add one foot of sludge to each tank. Winter sludge temperatures vary from 42° to 45° F., while in summer they reach 68° to 71°. It is noticeable in summer that at times a thin, black, dry scum, with fine surface cracking like that of digested sludge, forms, necessitating two-foot additions of raw

sludge to keep the tanks gassing. At summer temperatures the sludge digests at a rate greater than the raw sludge supply.

On the average, rarely more than half of the sludge in a tank is withdrawn, at which point the tank contains approximately 100,000 cu. ft. Therefore, a one foot addition amounts to 10 per cent, approaching 5 per cent as the tank is filled from period to period. As previously stated, sludge additions can be doubled in summer and still maintain satisfactory conditions. By this is meant that the sludge which is drawn has lost its objectionable odor and will drain well on sand beds.

Every three or four weeks, bottom samples of sludge are taken by a sounding rod, equipped with a bottle, from three points in each tank to obtain data on the character of the sludge. The per cent of volatile matter approximates 60 to 61, and the pH 6.7 to 6.9. Samples of sludge released to drying beds are collected every 10 minutes and composited for each individual tank. The quantity of sludge produced from digestion tanks averages 4.4 cu. yd. (90 per cent moisture) per million gallons of sewage.

Sludge Drying Beds.—Sludge is applied to beds at about 92 to 95 per cent moisture and 12 in. deep. The time interval between filling and removal has been as short as 10 days on several occasions, but under adverse weather conditions, rain and cold, the drying time increases to several weeks. Care is taken to fill the beds with reasonably heavy sludge so that the depth after drying will be at least 4 or 5 inches, for at lower consistencies the layer of dried sludge is thin, resulting in more frequent fillings and a consequent greater loss in sand adhering to the sludge at each removal. Prior to cleaning a compartment, six portions of sludge are collected, three on each side of the center opening, which are composited from all compartments in each bed cleaned. Where daily removals are from more than one bed, a composite from each bed is taken. Based on figures of the last three or four years, approximately 25,000 cu. yd. of sludge (average moisture 70 per cent) are removed from the sludge drying beds yearly.

Ultimate Disposal

Five or six years ago, disposal of the accumulated sludge from the beds presented a serious problem. Farmers took considerably less than the yearly production. In contrast to this situation, today we find the demand has increased to such an extent that during the last two years the disposal to farmers and other sources, which include municipal lawns and new ground surrounding a large manufacturing plant, averaged 37,000 cu. yd. or 50 per cent more than the yearly production. The reason for this change in the demand for sludge cannot be answered definitely, but it is known that the sludge is excellent for grass, and by ju-

dicious application with commercial fertilizer can be used to advantage with various crops. A typical analysis of sand-bed-dried sludge shows: nitrogen as NH_3, 2.2 per cent; phosphoric acid as P_2O_5, 0.5 per cent; and potash as K_2O, 0.2 per cent. Corn, cabbage and potatoes are numbered among the crops materially benefited by the sludge treatment as indicated by Keefer and Armeling ("Fertilizing Value of Baltimore Sewage Sludge," *Engineering News-Record*, Dec. 6, 1928).

Conclusion

Future developments at the Baltimore sewage treatment works are expected to be more radical than in the past. Dorr traction clarifiers, a new type of automatic screens and heated digestion tanks, are listed in the program. Dewatering of digested sludge by vacuum filters was started in 1931, but conclusions from these experiments as to efficiency from an economic standpoint cannot be drawn at this time.

B. L. Crozier is chief engineer of the Department of Public Works. George E. Finck, sewerage engineer, supervises the sewage works. C. E. Keefer is engineer of sewage disposal and G. K. Armeling, superintendent.

Discussion

R. Cleland, Pennsylvania State College: One of the statements was to the effect that they removed the sludge from the middle of the bed when the bed appears to be clogged. Has any one else had any experience or accomplished anything by doing this? We now are having serious trouble with our sludge drying beds refusing to drain the solids. The sludge of Baltimore contains 92 to 95% moisture. Our sludge averages 95% moisture. What are the results from other plants in this locality as to the moisture of sludge when it is taken from the Imhoff tanks?

C. C. Agar, N. Y. State Department of Health: I believe that most of the installations I am familiar with are of the Imhoff type. The solid content of the sludge is drained by the sludge treating beds. 70 to 80% is a fair average of solids content of the sludge. As to the other matter, I understand that a trench was dug through the sludge to hasten draining and drying of the sludge. I have had experience with sludge so deep on the sludge drying bed that we had to remove the top crust in order to expose fresh sludge for drying. I have heard of the method of going on a sludge drying bed and digging a channel through the bed when the sludge was partially dry to hasten the drying process.

Mr. Cleland: We have not been able to determine whether the trouble is with the sand or the sludge. Sludge will drain on one bed normally and will refuse to drain on another bed under similar conditions.

We draw sludge as frequently as we can. We are handicapped by inadequate sludge drying beds. The sludge at times is perfectly normal; at other times just the opposite.

H. M. Beaumont, Philadelphia: Just two weeks ago we found it necessary to remove the sand from two beds and in addition to remove all sand and grit and replace it with a clean river sand.

Mr. Agar: I would like to ask Mr. Cleland if the sludge he refers to has any odor.

Mr. Cleland: Normal odor, there seems to be a continuous film on the sand.

Comments on the Significance of Laboratory Tests at Sewage Treatment Plants*

BY CHARLES C. AGAR

Assistant Sanitary Engineer, New York State Department of Health, Albany

The disposal of human waste has been a problem ever since man was placed on the earth, and we can go back in the Bible to the 23rd Chapter of Deuteronomy, 13th and 14th verses, and find the following:

"Thou shalt have a place also without the camp wither thou shalt go forth abroad:

And thou shalt have a paddle upon thy weapon; and it shall be, when thou wilt ease thyself abroad, thou shalt dig therewith, and shalt turn back and cover that which cometh from thee."

That was the original method of sewage disposal. Even in those days they realized the importance of cleanliness or covering up and disposing of the excreta. In fact we have today a somewhat modified form of that same system of disposal in certain types of privies which are used and then filled in, moving the privy to another site. Along through the years the disposal of dry material or material without having excess water present was not such a complicated method, since the path of pollution from such excreta put into the ground was confined more or less to the immediate vicinity. And then in the old days the people did not congregate in such large communities as now. With the concentration of population and with the development of the water carriage system of disposal, we have the problem magnified a good many times. We are simply making the presence of that sewage felt in streams many miles from the source and pollution thereby can be carried so that it affects large areas and a large number of people. Within the last two decades there has been rapid progress in the art of sewage treatment, and when I say "art of sewage treatment" I mean that the sewage plant operation today has been raised to a higher plane than heretofore. It is now a profession of which an operator can well be proud.

Getting back to the title of this discussion, I might say that in order to determine the significance of laboratory work we must know first the purpose for which a plant was designed. It is obviously foolish to carry out regular bacterial analyses on sewage which simply passes through a screening plant. Therefore we want to know what the purpose of the plant is in order to enable us to determine what laboratory control work should be carried out. There are three types of nuisances or three purposes for which a plant may have been constructed. The first is visible

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nuisance. This is nuisance created by the presence of objectionable floating solids or objectionable material present in the watercourse into which the sewage is discharged. It also includes the sludge deposits in the bottom of a stream or along the banks of a stream. Then there is the organic pollution which brings about the reduction in the dissolved oxygen content of the receiving stream and subsequent putrefaction develops obnoxious odors. I might also include here the depletion of dissolved oxygen resulting in the death of fish and other clean-water organisms.

Lastly, there is bacterial pollution, occasioned by the presence of bacteria in the effluent from a plant or in the sewage discharge, which may be of a pathogenic nature. It is of human origin and can travel for great distances, causing infection of a large number of people.

In any laboratory work we cannot overemphasize the value of records of treatment plant operation, and this is especially true for the following reasons: First, it enables a plant operator to determine the efficiency of the plant, how well the plant has carried out the work for which it was built. Second, it enables the operator to get better control of the plant operation. In fact, with laboratory control work you can out-guess the plant and sort of anticipate difficulties and troubles. It enables the operator to make the necessary changes in operation so that he can avoid any serious difficulties. It also enables the collection of data for use of the designing engineer when enlargements or modifications of the plant are contemplated. It is valuable as evidence in case of law suits against the village or municipality alleging nuisance conditions or pollution of the watercourse by the plant effluent discharges.

There are various tests which may be used in a sewage treatment plant.

The first test, and probably the most universal in that it is adaptable to practically every type of treatment plant, is the settleable solids or Imhoff cone test. This test is carried out in glass cones tapering to an apex which is graduated. These cones hold approximately a quart, and the test is made by filling the cones with samples of the raw sewage and the tank effluent and allowing them to stand for two hours. The amount of solid material collecting in the apex of the cone is then read. We have a measure of the efficiency of the settling tank process, by taking the amount of material in the raw sewage settled in the bottom of the cone, subtracting from it the amount settled in the effluent cone, dividing by the total amount present, and multiplying by 100, which gives the per cent removal of the tank in settleable solids.

There are many modifications and refinements of the test, but ordinarily it gives an indication of the efficiency of settling tanks. It may also be applied to secondary settling tanks.

Then we have the putrescibility test, which is possibly not strictly accurate in all instances for the determination of anything that is definite,

in that it does not represent actual field conditions or approach stream conditions. Nevertheless it does give a measure of the strength of the effluent as far as oxygen demand is concerned. The test is a colorimetric one; a sample of the effluent is taken and an indicator known as methylene blue, an organic dye, is added and the mixture incubated at about 20 degrees centigrade. The bottle is observed every day, noting the time that it takes for the color to be discharged.

The next test in order of importance is probably the test for residual chlorine, where chlorination is practiced for effecting bacterial removal. Two methods are generally used for that test, and both show the presence of residual chlorine in the treated sample after a definite contact period; either the starch iodide test or the orthotolidin test. The latter is generally used.

The test that I am bringing up now is probably the most important and the best test that we have today to measure the efficiency of sewage treatment plants, namely, the biochemical oxygen demand determination. It is a measure of the oxygen absorbed by the sewage or the sewage effluent over a definite time period, usually five days.

All natural unpolluted waters have a definite dissolved oxygen content, and this oxygen is used up more or less when an effluent is discharged into the watercourse. If there is an insufficient amount of oxygen to satisfy the oxygen demand the stream will become septic, and you will have the development of odorous conditions. If, however, the amount of dissolved oxygen present is sufficient to satisfy the oxygen demand of the effluent you will probably have satisfactory conditions in the stream.

A depletion below two p. p. m. in the dissolved oxygen will kill the most sensitive fish, such as trout, by suffocation. The test is strictly biochemical and requires considerable equipment, but it is the best measure that we have today of the efficiency of the sewage treatment plant in its various units or in its entirety.

The dissolved oxygen test is a very valuable test which can be carried out on a stream or on an oxidized effluent to determine the presence of dissolved oxygen. You can usually consider that the presence of dissolved oxygen in an effluent is an indication that the sample is in fair condition. This is especially true of an activated sludge or a trickling filter effluent. If, in addition, it is clear and free of suspended material the probability is that that is pretty well treated.

Chlorides in a domestic sewage run from about 70 parts per million up to possibly 120 or 130 p. p. m. for concentrated sewages. Chlorides will vary in various parts of the state and are somewhat related to the normal chlorine content of the waters in the various sections. The chloride content of sewage passes through a treatment plant without any appreciable change or any detectable change in concentration, so that over a period

of time the determination of chlorides will be a rough check on the dilution of the sewage or the sewage flow coming into the plant. That means that if the chlorides drop appreciably you will know that there is more infiltration, say, coming into the sewer system, or if the chlorides increase it is a fair indication of an increase in the concentration of the sewage.

The suspended solids determination is a filtering test, the samples being filtered through an asbestos mat. The Gooch crucible method is usually used. This removes the suspended material in the sample, but does not remove the colloidal material.

The organic nitrogen determination is a measure of the total nitrogen in sewage. It is usually carried out by digestion with sulphuric acid, neutralization with alkali and distillation to obtain the results in terms of ammonia.

Nitrates are determined to estimate the nitrogen which is in an oxidized state. The nitrogen tests are used in some plants to measure the efficiency of a plant in stabilizing the nitrogen that is present in the raw sewage and subsequently oxidized in the treatment plant. The nitrites are only slightly a less stable form of nitrogen than nitrates, and frequently nitrites and nitrates are determined at the same time.

I shall now mention bacteriological examination of samples and their significance. The particular application would be of course in plants where it is necessary to discharge a sterile or practically sterile effluent for protection of shellfish areas or protection of water supplies. In sewage work it is only necessary usually to carry out the presumptive *B. coli* test either with the standard lactose broth or the brilliant green medium.

Now we come to sludge solids. I left this until last, not because it is unimportant but because it does not relate particularly to the process of passing sewage through the treatment plant and determining the quality of the effluent. After the solids have been removed from sewage, either in the primary or secondary settling tanks, there is an accumulation of solid material. The tests of sludge solids are carried out in order to determine the nature and concentration of the solid material in either the fresh or the digested sludge.

The most common method of determining concentration of solids is by placing some of the sludge, fresh solids or digested material in a dish of platinum or, usually, nickel, and evaporating to dryness, and by the difference in weight of the dishes and the weight of the residue in the dish obtaining the solid content in percentage of the wet sample. The dried sample may then be ignited and the organic material and volatile ingredients driven off, leaving an ash in the dish. This gives a determination of the volatile or organic content of the sludge sample. This test enables us to determine the condition of sludge in a digestion tank, for

we can determine the degree of digestion obtained, knowing the amount of organic material in the primary sludge, and usually assuming that a well-digested sludge should have that organic material reduced about 50 per cent in the digestion process.

I want also to mention the colorimetric hydrogen-ion test for sludge to show the condition of digesting sludge. The scientific or technical explanation of hydrogen-ion concentration is rather complicated. Probably all that will be necessary to say is that a hydrogen-ion concentration greater than seven indicates an alkaline condition, and a hydrogen-ion concentration or pH value below seven indicates an acid condition. For digestion of sludge a pH of over seven is of course desirable for good digestion. This test is carried out in a variety of apparatuses. The sludge is prepared either by filtering or by centrifuging or by dilution. Filtration seems to be preferable, although there is a question about this method because of possible loss of carbon dioxide in filtering the sample, thereby raising the pH value. When using the dilution method and adding distilled water to not over 10 to 15 times the quantity of sludge, sufficient supernatant or clear liquid can be withdrawn and put into a small tube to which an organic dye is added, which develops a certain color with different pH values. The brom-thymol blue indicator is probably as satisfactory for most plants as any, and covers a range that is most apt to be found, the range being from 6 to 7.6. Glass discs are used for colored standards, and the claim is made that they are permanent and do not fade. There are also several other very satisfactory pieces of equipment on the market, consisting of tubes in which the color standards are sealed. They have been in use for a number of years and have proved very satisfactory for all ranges of pH work.

I think in a general way I have covered some of the more common tests that are made at a sewage treatment plant. There are a large number, of course, that have not been covered because of their somewhat doubtful significance. I have omitted, for instance, the oxygen consumed test which is more or less a chemical test of the amount of permanganate that is used up by a sewage sample in a given time at boiling temperature. This test can be used to get relative information and until the development of the B. O. D. test it was used to determine the efficiency of plants.

In case a text book or the instructions for carrying out these various tests is desired, there is no better book than the "Standard Methods for the Examination of Water and Sewage," issued by the American Public Health Association, 450 Seventh Avenue, New York City. These cost $1.50, and a new edition is now being prepared which will contain all the recommended modifications of procedure for both water and sewage treatment plant analyses.

Discussion

The Chairman: You operators, especially those whom Mr. Agar puts on the carpet, will now have a chance to put him on the spot, so go after him as hard as you want to.

Mr. M. Cohn: Mr. Agar referred to the various benefits of keeping analytical records at a sewage plant. It just so happens that he mentioned the various benefits that pertain primarily to the plant itself. He mentioned the fact that the records enable the operator to determine the efficiency of operation, to give better control and to secure data for new design. Those are all absolutely true. But sewage treatment to my mind is one of the most broadminded professions that modern times has brought us. I suppose it has to be broadminded since we are drinking everybody else's diluted sewage up-stream ever since the Israelites stopped scratching around with a paddle and dumping their sewage into the water courses of the land. But that brings me to the point I want to make and that is this, that one of the primary benefits of sewage analysis in this broadminded field of ours enables the other plant operators to see what you are doing and to compare his efficiency with yours, and spurs him on to do the kind of work that you are doing or spurs us on to do the kind of work that he is doing. That brings us again to the necessity for specific standard methods of analyses, and I am glad that Mr. Agar mentioned the sewage analyses cook book that is available. I have devoted stress to the fact that if you are going to compare your result with everybody else's that your samples must be strictly according to Hoyle. Otherwise you may go off on a tangent and report results which somebody else can't get. You may have some poor operator scratching around to produce an efficiency which is almost impossible to produce, just because you produced it. Mr. Dappert talks about the significance of the chloride test, and I can't resist the temptation of telling about a humorous experience which we once had, which relates to the significance of chloride going through a treatment process unreduced, and also the travel of the pollution underground. We have a concrete intercepter running along under the sidewalk of a street in Schenectady, and we received a complaint from a neighboring house that there was water in the cellar, that water continually leaked into the cellar. The sewer bureau passed the buck to the water bureau and the water bureau passed the buck to the sewer bureau, each one contending that it was the other fellow's conduit. It seemed a simple thing to go in and take a sample of the water in the cellar and run a chloride test on it and tell very quickly whether it was sewage or whether it was water. We went down into that cellar and found about four feet of water in it, downstairs, of a speakeasy, incidentally. We took a sample, and I expected that the chloride would run about 4 p.

p. m., or perhaps 40 p. p. m., and to my surprise it ran 40,000 p. p. m. The chloride test didn't work out. I went back there the next day and tried to find out what happened, and on my second visit I noticed there were a few empty beer kegs floating around on top of the water. I finally succeeded in getting the speakeasy owner to admit that he had been making some beer down in the cellar, and he had been using a large quantity of salt to give his beer a snap and he sprinkled the salt very generously over the cellar floor.

The Chairman: Has some one else anything to contribute?

Mr. J. F. Skinner: I would like to make a very brief statement, not from a chemist's standpoint. Some years ago in visiting various plants I was impressed with the large amount of analytical work that was done and by the wretched operation of the plants. The attempt seemed to be to show why they were not working nicely. I think it is far more interesting to see a plant designed with sufficient care and sufficient liberality so that it is not overloaded at once, especially in the smaller plants where there isn't a chance for a chemist, where the operator is taught to do a few things, to have him taught to do those few things such as you are giving him in a short school, to make those with great regularity and keep a definite record.

Mr. Agar: I might just relate a humorous incident to show what an operator will do sometimes if he does not understand exactly what each test is for or how the test is to be carried out. I had occasion last week to inspect a plant and I found that the operator was determining the pH value of his sludge rather faithfully, but he had run out of the ordinary brom-thymol blue indicator, and he had substituted methylene blue and was getting a very satisfactory blue color, indicating a high pH in his samples. That did not mean a whole lot to him. A blue dye was all right to use there. If they got a blue color it was all right.

The Chairman: He had not been through the short school?

Mr. Agar: No, he hadn't.

Mr. Cohn: We in Schenectady very seldom produce a sludge on the alkaline side of the scale, yet two weeks ago they brought a sample into the laboratory from the sludge beds, and the pH ran 8.7. That was something to think about. Suddenly our tanks had gone alkaline. I checked back and found that one of the men had been mixing lime for white-washing some concrete posts. After he was done with that, the fellow that was sampling the sludge bed had taken that same pail and sampled his sludge in it.

Mr. Schaf: Are the methods of sampling as standard as the laboratory test? Can we determine the relative efficiency of the various plants by different methods of sampling? I would like to ask Mr. Agar whether the state will recognize any definite method of sampling of the sewage?

Mr. Agar: There are definite methods of sampling applying to each particular plant. There is no general rule as regards sampling. It depends a whole lot on the facilities of the laboratory, the amount of personnel they have, whether or not it is a 24-hour operation. Probably the most satisfactory method of getting a picture of the plant's efficiency is by collecting samples hourly through the various parts of the plant, and making analyses of the 24-hour composite of such samples. Obviously this cannot be done at a large number of the plants in this state, so, in order to get data on a particular plant for relative efficiency of operation from day to day or from month to month, we have attempted to have the samples taken and the tests made at the time of day when that plant is under the greatest load, when usually the largest volume of sewage reaches the plant. This usually happens about 10 or 11 o'clock in the morning, depending on the time of concentration of the sewage in the sewage system and at the treatment plant. The test carried out daily in the same way at the same plant will give data which will show whether the plant is continuously operated efficiently or not. For instance, if the settleable solids content starts to increase in the effluent of the plant you know that something is wrong. The samples are taken at the same time every day and the other conditions remain about the same. If the solids increase it is time for the operator to begin to look around for the reason. If it happens to be a trickling filter it may be the unloading of the trickling filter. There is a reason for every particular change in the data that is secured on a plant operation.

Mr. Sprengart: May I ask Mr. Agar if he does not think a 37° C. bacteria count at various times of the year is necessary on sludge?

Mr. Agar: I haven't ever had occasion to recommend that. There may possibly be some significance to such a test, in determining the bacterial content. I think if that work was going to be carried out probably the best thing to do instead of total counts would be to make a microscopic examination and determine the presence of typical flora and fauna in the sludge. Of course we know that the bacterial content will go down in the winter and usually it will go up in the summer. I doubt very much if such counts have much practical application.

Mr. Sprengart: The reason I asked that is that I have seen sludge run down to about 20,000 per cc. and then again up to 800,000 per cc. due to solids being present in the sludge and not well digested.

The Chairman: Shouldn't that be encouraged as a research problem?

Mr. Agar: Yes. It probably is true that there has not been enough work. There may possibly be a relation between digestion and bacterial content.

Mr. L. H. Enslow: Just as a matter of interest, I was talking to Dr. Rudolfs two years ago when he was making his investigations, in

the early stages of it. Dr. Rudolfs told us the best digestion occurred with the least number of bacteria. I asked him how that came about. He said he meant the least amount of bacteria that he could count on an agar plate. So that if you are going at this problem it appears you would have to study the anaerobes rather than the aerobes.

Editorials

Vacuum Filtration of Sludge

The data presented by Keefer and Cromwell on the vacuum filtration of sludge at Baltimore should be studied carefully by all who are interested in the trend of developments in the disposal of sewage sludge. This is the first publication of detailed results of operation, although it has been known that extensive experimental work on vacuum filtration of sludge has been under way for the past year or two at Baltimore, Chicago, Columbus, Los Angeles and North Toronto. Activated sludge has been filtered on a large scale for a number of years at Milwaukee and Pasadena, but as yet the vacuum filtration of settled or digested sludge has been attempted only on a small scale, with the exception of the large-scale plant of the Sanitary District of Chicago, which has a capacity of 20 tons of dry sludge per day.

This activity presages a new era in sludge disposal. Sand beds have probably reached their ultimate development with the mechanical cleaning devices in use at the Chicago West Side Works, and the large glass-covered beds that have been proposed for the Cleveland Easterly Works. Notwithstanding the mechanical improvements for large-scale operation, sand-bed drying is still essentially a seasonal operation. Vacuum filters, however, can be used throughout the year, thus obviating winter storage of digested sludge, as well as replacing the large areas of sand beds and cleaning equipment now required.

The investigations at Chicago have been directed particularly toward the filtration of fresh plus activated sludge. The filter cake becomes quite odorous, however, on storage and must be incinerated for final disposal. With digested sludge, odors will probably not be objectionable, but the question may be raised as to whether disposal of sludge containing 75 per cent of water is a completely satisfactory procedure. This seems to be a very wet material to be dumped in deep piles. If removed as fast as produced and used for fertilizer, such high moistures are probably not objectionable, apart from the necessity of transporting so much water.

The high rates of filtration now demonstrated are noteworthy. Whereas rates on activated sludge at Milwaukee and Pasadena have been approximately 1 to 2 pounds per square foot of filter surface per hour, the Baltimore rates reached a maximum of 20 pounds, and an average of 14 pounds. This great increase is due to the different character of the sludge, the lower moisture content, and the more rapid speed of the filter drum, with less

submergence. Likewise it remains to be demonstrated whether the high rates at Baltimore will be duplicated by operation of large filter units on a plant scale.

The successful filtration of all types of sewage sludge is made possible by the use of ferric chloride for coagulation. This coagulant is so superior to all others that its use is almost universal. But it is astonishing to note the magnitude of the cost of ferric chloride. Mr. Keefer's cost data indicate that out of a total cost per ton of $4.22, ferric chloride amounts to $2.36, or 56 per cent. Besides the objection of expense, ferric chloride is troublesome to handle because of its intense corrosive action. These objections make it highly desirable to find some other cheaper coagulant or filter aid if such material can be found.

With regard to the Baltimore cost data, the allowance of only $1500 per annum for labor would seem to be quite low, for the operation of two (or four) filters, control of coagulant, disposal of about 150 tons per day of filter cake and repairs to the filters. The cost of filter cloth and wire also seems to be missing, unless included in the item of 20 cents per ton for "coal, oil, etc." Even allowing a substantial charge for miscellaneous items, however, the cost of vacuum filtration would still appear to be less than the cost of sand bed drying at $6.23 per ton of dry solids. Costs at other places might be quite different from those at Baltimore, due to different wage scales and different costs of electric power or ferric chloride.

There is a question as to whether it is or is not preferable to dewater and incinerate fresh sludge rather than to digest and dewater digested sludge. In the former case the sludge has a much higher B. t. u. value, on the dry basis, and of course the entire cost of digestion tanks is saved. In the latter case it is apparently unnecessary to incinerate the sludge, at least from the standpoint of odor. Various other advantages or disadvantages must be compared in order to determine the relative merits of mechanical disposal of fresh *vs.* digested sludge. For large projects incineration certainly provides the ultimate in disposal of the solids. The work at Chicago has been almost entirely on the handling of undigested solids, although test runs are to be made at the 20 ton plant, now in operation, with digested sludge from the Imhoff tanks. The Chicago work is also different from that at Baltimore in that activated sludge must be disposed of, whereas at Baltimore only settled sludge has been treated. The problem of disposal of activated sludge, either by digestion, filtration or incineration, is admittedly more difficult and more expensive per ton of dry solids than the disposal of settled solids.

The possibilities for improvements in mechanical disposal of sludge are tremendous. The vigor with which the problem has been attacked during the past year gives promise that new methods and new equipment will be adopted during the next few years. It is interesting to recognize the

start of a new cycle in sludge disposal. The paper by Keefer and Cromwell may be considered as a landmark in this development.

Selling Sewage Treatment on Facts—Not Fancy*

In these times of curtailed outlet for industrial enterprise, individuals and corporations are looking, with a covetous eye, at the field of municipal undertakings and improvements. This will be even more true if funds for construction of public works and utilities become available from the Reconstruction Finance Corporation. Included in this program will be the construction or extension of sewerage and sewage treatment works.

Corporations having a staff of engineers and chemists, while casting about for new business and endeavoring to make the fullest possible use of existing facilities and personnel, in some instances have become attracted to one of the frequent municipal undertakings—sewage treatment and waste disposal. They see in sewage treatment a relatively undeveloped field with an apparent ample opportunity for the production of less complex, more practical and less costly processes than are now employed. As to the treatment of industrial wastes, there seems to be an even greater field in view. Some promoters have an idea of developing self-supporting features with by-product recovery from the treatment and disposal of the polluting materials at the minimum cost and without regard to attempted recoveries of by-products. Still others have no interest in process development, but see only an outlet for mechanical units which may be applicable in one or several existing or proposed processes.

All or any of the proposed or projected schemes can work to the good of sanitation development by giving impetus to the movement toward stream cleansing, now well under way in America. If this new undertaking, strange to individuals and corporations uninitiated in the basic principles of waste treatment and requirements in stream pollution correction, is adequately guided by experienced engineers and chemists qualified to advise in such matters, the way will be smoother, and progress sounder and more rapid in the long run. Such advisers or consultants must be competent to understand what is required in the matter of degree of purification in given instances; wherein a particular process may be adequate or inadequate; wherein it will be able to produce results alone or may require amplification to the extent of some secondary treatment, biological or chemical. So far there has not appeared a simple and economical process which can be considered ample under all circumstances of stream condition and waste treatment and it does not seem

* *Editorial reprinted from the October, 1932, American Journal of Public Health, by permission of the Editor, Dr. Mazÿck P. Ravenel.*

probable that a single process will answer. There is need for greater flexibility than is economically procurable from a single process and it will be necessary for those developing new and unproved schemes to consider this feature carefully.

In marketing new schemes, or old ones which have been improved and amplified it will be necessary to "sell" on *fact* and not on *fancy*. The process which produces an effluent pleasing to the eye, without odor nuisance and void of elements dangerous to human or animal health, will answer the requirements in a great majority of instances, but there will be others wherein the residual but invisible organic matter in such an effluent may be more than the stream can assimilate during the critical periods when flows are deficient. During such periods amplification of the otherwise satisfactory treatment may prove essential.

Mechanical or chemical engineers thoroughly competent to develop industrial processes, and already proved successful in their field, may find themselves poorly understood by the sanitary engineer or the chemist of experience in stream pollution matters. These same men with the assistance of the experienced sanitarian, working in close coöperation and acting as an interpreter of the language and view-point of the state and national health departments or stream pollution commissions, may produce a process of waste treatment superior to any yet developed.

Producing and marketing novel processes and equipment for sewage treatment has not proved and will not prove as simple as the producers may expect, and much confusion will result unless these producers or promoters market the process on a sound technical basis with the aid of staff members or counsel qualified to evaluate pollution conditions and definitely assure economically sound performances commensurate with requirements. Disregard of such principles in marketing new sewage treatment processes by attempting to "sell" by other and less sound methods has not met with any real and material success in the past nor will it now

Proceedings of Local Associations

California Sewage Works Association
Fifth Annual Convention

San Diego, September 26 and 27, 1932

More than 120 members and guests attended the Fifth Annual Convention of the California Sewage Works Association at San Diego. The program included an inspection trip to plants in San Diego County, excellent papers with interesting discussions, a business meeting with committee reports and election of officers, and an entertaining dinner meeting with a humorous series of letters read by Prof. Leon Reynolds.

An automobile caravan of about 30 cars assembled at Oceanside City Hall at 8 A.M., Monday, September 26. The local committee, under the chairmanship of Ed Beale, gave each member mimeographed statements of the interesting features of the plants to be visited, including the Oceanside septic tank, Carlsbad separate sludge digestion plant, Vista covered Imhoff tank and sprinkling filter and Escondido activated-sludge plant. At the Escondido plant R. F. Goudey gave a demonstration of bulking and debulking activated sludge and explained the phenomenon, which he said was largely or entirely mechanical or physical.

A luncheon was served to 98 members and guests at Escondido.

The first session was held at the U. S. Grant Hotel in San Diego. The meeting was called to order by President Allen, and the following papers were read:

"San Diego State Teachers College Plant," by B. D. Phelps.

"Sewage Analyses and What They Tell the Operator," by E. A. Reinke. This paper was discussed by T. R. Haseltine, R. F. Goudey, Jane H. Rider and D. Travaini.

"Unusual Conditions Encountered in Sanitary Sewer Design and Construction," by Chas. H. Lee. This paper was read by Walter N. Frickstad, City Engineer of Oakland, and discussed by A. M. Rawn and C. C. Kennedy.

"Chemical Sewage Purification at Palo Alto," by R. A. Stevenson. This paper was discussed by H. O. Banks, A. M. Rawn and Dr. P. J. Beard.

A dinner meeting was held at 7 P.M., followed by an interesting talk by Professor Leon B. Reynolds entitled "A Sanitary Correspondence" featuring a series of letters written by two sewage plant operators.

On Tuesday morning at 9 A.M. the annual business meeting of the Association was held.

Membership Committee: J. A. Harmon reported 220 members, a net loss of 17.

Publicity Committee: John Spencer reported little success in getting newspaper publicity for meetings.

Legislative Committee: J. C. Albers reported much activity on sewer rental bill to be reported in detail at joint meeting with Engineers Section of the League of California Municipalities.

Auditing Committee, consisting of M. L. Crist, H. E. Shook and A. P. Banta, reported Treasurer's books satisfactory. Moved, seconded and carried that report be accepted.

Resolutions Committee, consisting of C. C. Kennedy, J. C. Albers and A. M. Rawn, reported resolutions on safety regulations for workers in sewers, thanks to local committees and congratulations to Professor C. D. Marx of the engineering committee of the Reconstruction Finance Corporation.

The Secretary-Treasurer's report was read and accepted.

Award Committee: Considerable discussion resulted from the suggestion of the committee that the award be given only for some outstanding work. It was finally moved, seconded and carried that the plaque be given as heretofore, but no cash award be made.

Licensing of Operators: Moved, seconded and carried that a committee of three be appointed to report at next annual meeting.

Sewage Research: Past-President B. J. Pardee spoke in favor of keeping sewage research alive even if funds could not be made available at present, and the President announced that would be the policy since there was no objection.

Nominating Committee: J. F. Smith, Chairman, presented the report of the committee and named two each for the offices of President and the two Vice-Presidents. C. C. Kennedy spoke in favor of continuing the policy of advancing the Second Vice-President to First Vice-President and President, stating that such a policy was agreed on at the time of organization largely on the advice of George W. Fuller. Mr. Kennedy felt that a large measure of the success of the Association was due to this policy of getting men on the Board two years before being elected President. After considerable discussion the report of the committee was accepted. H. B. Hommon by mail withdrew his candidacy for President in favor of First Vice-President Jacobson, who was unanimously elected President. R. F. Goudey withdrew as a candidate for First Vice-President in favor of Second Vice-President McMillin, who was unanimously elected First Vice-President. T. R. Haseltine was elected Second Vice-President; W. A. Allen, Director; A. M. Rawn, Board of Control Member; and E. A. Reinke, Secretary-Treasurer.

Following the business meeting three papers presented at the Yosemite meeting were discussed.

"New Thoughts in Sedimentation," by Chester A. Smith, was discussed by C. C. Kennedy, A. H. Koebig, E. A. Reinke, R. F. Goudey, T. R. Haseltine and A. M. Rawn.

"Digestion and Disposal of Sewage Sludge," by R. F. Goudey, was discussed by M. L. Crist, R. A. Stevenson, E. A. Reinke, R. F. Goudey and T. R. Haseltine.

"Digestion of Garbage in Beccari Cells with Analogies to Sludge Digestion Problems," by Prof. C. G. Hyde, was discussed by A. M. Rawn and P. J. Beard.

Luncheon was arranged by the local committee. R. M. Gregory, Director of Public Works, welcomed the Association on behalf of the city administration.

A joint meeting with the Engineers' Section of the League of California Municipalities was opened by G. H. True who turned the gavel over to President Allen.

Chairman J. C. Albers and W. T. Knowlton of the Legislative Committee reported on the Sewer Rental Bill, announcing support by the League and by the State Department of Public Health. Members were urged to contact their representatives in the State Legislature.

Papers were presented as follows:

"Operation Experiences at Phoenix, Arizona, Plant," by Dario Travaini. This was discussed by Jane H. Rider and C. C. Kennedy.

"The Control of Anaerobic Decomposition in Sewage Transportation," by A. P. Banta and F. D. Bowlus. This paper was discussed by O. E. Steward, C. T. Henderson and E. A. Reinke.

"Water Contamination from Toilet Flush Valves," by Walter Putnam. This was discussed by Dr. Carl Wilson and Jean Vincenz.

President Allen turned the meeting over to President-elect Jacobson who thanked the members for electing him and asked their support for the coming year. The meeting was adjourned.

E. A. REINKE, *Secretary*

Note: On the day following the meeting some two dozen members were conducted by the local committee on a trip to other sewage treatment plants near San Diego, including State Teachers' College, County Farm, El Cajon and one of the ocean outfalls for a portion of San Diego.

Missouri Water and Sewerage Conference

Eighth Annual Meeting

Sedalia, October 13–14, 1932

The Eighth Annual Meeting of the Missouri Water and Sewerage Conference was held in Sedalia, Thursday and Friday, October 13–14, 1932. The registration was the largest ever recorded by the organization.

One formal paper was presented at the beginning of each half-day session of the meeting, the remainder of the session being devoted to round table discussion.

After an address of welcome Thursday morning by the Honorable W. Steeples, Mayor of Sedalia, a series of papers was presented dealing with water purification.

Thursday night, almost 100 people attended the annual banquet, which was presided over by Mr. H. A. Gallagher of Independence as toastmaster. Following the banquet, the guests enjoyed a technicolored talking picture describing the "Lake of the Ozarks." This talking picture was made at the Union Electric Company's new $30,000,000 hydro-electric project on the Osage River, which has been impounded to form America's largest artificial lake.

The Friday morning session was devoted to a discussion of sewage treatment topics. At this session, a paper entitled "Recent Developments in Sewage Treatment" was presented by G. R. Scott of Kansas City. This paper was illustrated with motion pictures. Round table discussions on the following subjects were opened by the men indicated: "Laboratory Control of Sewage Treatment Plants," by R. E. Fuhrman of Kansas City; "The Collection of Gas for Heating Sludge," by George S. Russell of St. Louis; "Sewer Rental Charges," by H. C. Delzell of Chicago, Illinois; "The Degree of Treatment Necessitated by Various Types of Streams," by W. Scott Johnson of Jefferson City.

After the morning session, the Sedalia Water Company's filtration plant was inspected. After the inspection the convention enjoyed a luncheon at the Sedalia Country Club as the guests of Mr. L. P. Andrews, President of the Sedalia Water Company. Following the luncheon, the Sedalia sewage treatment plants were inspected. Sedalia is served by two plants, one an Imhoff tank and trickling filter built in 1915, and the other a separate sludge digestion and trickling filter plant built in 1927.

The following officers were selected for the ensuing year: *Chairman*, W. E. Barnes, Liberty; *Vice-Chairman*, L. P. Andrews, Sedalia; *Secretary-Treasurer*, Herbert Bosch, State Board of Health, Jefferson City. *Executive Committee:* C. E. Hord, Louisiana; M. S. Hogan, West Plains; H. E. Newell, Webb City; Frank Turner, Cameron.

HERBERT BOSCH, *Secretary-Treasurer*

New York State Sewage Works Association

Annual Fall Meeting

Saranac Lake, October 14–15, 1932

The New York State Sewage Works Association held its Fall Meeting at Saranac Lake, October 14–15, 1932, President Earle B. Phelps presiding.

The setting in the heart of the Adirondacks with the marvelous fall coloring and the cordial hospitality of the village will long be remembered.

Seventy-three members and guests were registered. The ladies continue their interest in these meetings, twenty-three being present.

Following registration Friday morning an inspection and sightseeing trip was made to the Lake Placid Sewage Treatment Plant, the Olympic Arena and the Olympic Bob Sled Run.

In the afternoon, after a brief business session, the following three papers were presented. In the first, "Approach to City Saved by Sewage Works—The Special Features of Design, Construction and Operation of These Works," Henry W. Taylor described the works at Saranac Lake and brought out a number of points in design and operation that had been established. Ellis K. Phelps presented the joint paper by Earle B. Phelps and himself on "Studies of Sewage Disposal in a Harbor Involving Bathing Beach and Shellfish Pollution," describing the problem, the methods and results of their work in the harbor. In the third paper "Maintenance and Operation of the Sewer System and Sewage Treatment Works of the West Long Beach Sewer District," George Nesbit, Superintendent of Sewers of the West Long Beach Sewer District at Atlantic Beach, N. Y., discussed his problems in maintaining an extended sewer system with minimum grades, involving several lift stations and an ocean outfall and operating a sewage treatment works entirely below ground level. All the papers provoked considerable discussion that was strictly to the point and instructive.

The members and guests were guests of the village at an informal dinner in the Hotel Saranac. C. C. Trembley, M.D., presided as toastmaster and introduced the Hon. Seaver A. Miller, Mayor of Saranac Lake. Mayor Miller in a delightfully informal talk gave his personal recollections of Saranac Lake and the central Adirondacks.

An innovation on the program was a so-called Sunrise Breakfast on Saturday, which fifteen ladies graced with their presence and then modestly withdrew when Morris Cohn and C. C. Agar opened up the Question Box. The answers were short and snappy. Following this the meeting took up the round table discussion with Vice-President A. F. Dappert presiding. Arnold Hale of Brighton opened the discussion on "Winter Operation of Sewage Treatment Plants;" F. A. Cary of Fairport and Harry Eustance of Ithaca on "Conditioning of Sludge in Separate Sludge Digestion Tanks;" and C. C. Agar on "Artificial Treatment of Sludge to Facilitate Drying."

The meeting unanimously adopted a resolution protesting against drastic or unproportionate reduction in maintenance funds for municipal sewage treatment works.

The meeting was brought to a close with an inspection trip to the Saranac Lake Treatment Plant.

On Friday afternoon the Saranac Lake Women's Club provided a most interesting sightseeing trip in the village and vicinity and served tea in the Parish House.

The Fifth Annual Meeting of the Association will be held in New York City in January, 1933.

A. S. BEDELL, *Secretary-Treasurer*

Resolution

Presented and unanimously adopted at the Fall Meeting of the New York State Sewage Works Association at Saranac Lake, N. Y., October 14–15, 1932.

"In the interests of economy, municipalities in New York State have reduced or are contemplating the reduction of operating and maintenance funds at sewage treatment works.

"The New York State Sewage Works Association recognizes the need for economy in municipal government and favors all possible economies in sewage treatment, but views any serious reduction in operating and maintenance funds as a menace to public health, to the water resources of the State, to the sanitary progress of the State and to the physical condition of the existing treatment plants.

"*Be It Therefore Resolved:* That the New York State Sewage Works Association protest against any drastic or unproportionate reduction in operating and maintenance funds for sewage treatment by municipalities."

Employment Service

Editor's Note.—Chairman Emerson has suggested that the Federation might be of service to the members by providing the opportunity for listing applications for employment. The deplorable conditions of unemployment among skilled engineers, chemists and plant operators call for sincere measures of assistance by those in position to provide relief. Accordingly we have decided to establish an employment service section in this journal. Those out of work are invited to send condensed statements of their qualifications and experience to the secretary of their local association, who will approve or rearrange the statements and forward them to Mr. Moses for transmittal to the Editor for publication. Applications for listing in the January, 1933, Journal should be sent to local secretaries as listed in the January, 1932, issue, pages 177 to 180.

Employers should send their statements directly to Mr. H. E. Moses, Pennsylvania State Department of Health, Harrisburg, Pennsylvania. It is to be expected that there will be few, if any, notices of open positions, but applicants for positions need not be discouraged by this situation. If

their qualifications happen to be suitable for a particular job, correspondence between the employer and Mr. Moses may take the place of a printed statement.

There will be no charge for this service to members of the Federation or to employers, but the Chairman and Editor will decide the size and frequency of applications to be permitted, and the small charge to non-members, after the service is established. For insertions to appear in the next issue (January, 1933) unemployed members are urged to write immediately to their local secretaries. Those who are now employed are not invited to use this service merely to seek a better position. The local secretaries will decide the merits of each application.

This is somewhat of an emergency decision, but the need is obvious and the motive is sincere. The service will be justified if only a few men are placed in positions. Therefore, *write to the secretary of your local association.*

Reviews and Abstracts

The Present Condition of Our Rivers from the Standpoint of Pollution

By Dr. E. C. Dee

The Surveyor, **82**, 53–7 (July 15, 1932)

This paper was presented before the annual summer conference of the Association of Managers of Sewage Disposal Works by the author, who is the Technical Advisor to the British Ministry of Fisheries. The subject is discussed primarily from the view-point of the fisheries interests.

Fish life is perhaps the fundamental criterion of permissible pollution, and in many streams there is a very narrow margin between safety and harm to fish. Moreover the limit of permissible pollution is not readily determined by visual appearance of the water but must be established by chemical or other tests. Where fish are killed in bulk, the cause is usually the discharge of toxic substances such as creosote, sheep dip, tar, rain washings from tarred roads, etc. In cases where fish are not killed but are unable to maintain themselves, identification with pollutional conditions is frequently more difficult. In general, the condition of a river can be judged by the aquatic life which, under normal conditions, is moderately abundant and well balanced in species both vegetable and animal. Water "in which fish and stream life will flourish has, at any rate, a high concentration of dissolved oxygen, is fairly free from substances, both soluble and insoluble, which absorb dissolved oxygen, is approximately neutral in reaction and free from specific toxic materials like tar products or sheet dip, which adversely affect living protoplasm."

Chemical tests are therefore of value in estimating the condition of rivers. Of these the dissolved oxygen determination gives the most information with the least expenditure of time, trouble and money. Except in special cases abundant supplies of dissolved oxygen (above 70 per cent of saturation) connote good conditions for stream life. By plotting the oxygen saturation of samples from streams against distances between the source of such samples the oxygen gradient is obtained, the slope of the curve indicating the condition of the stream. Thus if the curve is fairly flat and the oxygen percentages fairly high, little wrong will be found in the absence of toxic materials. However, if the gradient falls sharply and then starts to recover, a source of major pollution is indicated. Meth-

ods for carrying out river surveys are described, including the tests for dissolved oxygen and ammoniacal nitrogen. When the nitrogen does not exceed 0.2 p. p. m. and the dissolved oxygen saturation remains above 70 per cent the general conditions of the water and of the stream life are satisfactory.

As regards control of pollution, the limits of suspended matter and dissolved oxygen absorbed, recommended by the Royal Commission on Sewage Disposal (1914) with the accompanying suggestion of relaxation of the standard where the conditions of dilution justified it, have been of the utmost value to the local authorities in the production of satisfactory sewage effluents. The consistent application of these recommendations limiting sludging and putrescibility gives adequate protection to stream life under normal conditions. However, owing to the varied character of polluting agencies, particularly from industry, it is frequently difficult to assess responsibility and apportion the burden of effluent purification.

Much yet remains to be done to raise the level of stream sanitation to a point where the dissolved oxygen gradients are at all times satisfactory. In the case of storm sewage discharge where usually no treatment is provided in excess of six times the dry weather flow, such storm water may be highly injurious and nullify the benefits of normally good effluents, especially in industrial areas. Again additional attention should be directed to the tidal estuaries which are frequently not so well protected from pollution as are the non-tidal streams

In the discussion of this paper Mr. E. Halliwell, Chief Inspector of the Ribble Joint Committee, agreed that the normal effluents from sewage treatment plants were not the greatest source of pollution troubles but that the untreated or partially treated wastes are mostly responsible. To base the need for the treatment of trade waste upon the preservation of fish life, however, in a highly industrialized area gains no support from local authority or manufacturer. Mr. F. W. Harris questioned the necessity of maintaining 70 per cent dissolved oxygen saturation for fish life and suggested 50 per cent as a more practical lower limit. Dr. E. Ardern questioned the economics of applying one standard to all of the rivers of the country and requiring that the maintenance and culture of fish life should be the standard for all streams. Although the ideal would be restoration of all streams to their pristine purity, yet, in highly industrialized areas, purification of wastes to such an extent as to eliminate health hazards and nuisance only is about as far as is practicable to go for the present.

A criticism of the present chemical oxygen test of the Royal Commission was expressed (after the meeting) by Mr. J. W. H. Johnson in that it failed to record more than 25 per cent of the readily oxidizable

matter in sewage and was in serious need of revision. Expensive river surveys using such inadequate procedures failed to define and measure pollution. J. K. HOSKINS

River Pollution Research. The Tees Survey: A British Association Discussion

The Surveyor, **82**, 297 (September 30, 1932)

In view of the increasing dependence on surface sources of water supply in Great Britain, the discussion of water pollution, with particular reference to the scientific survey of the River Tees, at the recent meeting of the British Association for the Advancement of Science, aroused much interest. In this connection some important points were brought out by staff members of the Water Pollution Research Board. (See THIS JOURNAL, **4**, 2, 369–73 (March, 1932).)

In his opening remarks, Dr. H. T. Calvert, Director of Research for the Board, in sketching the history of the Board's activities beginning in 1927, noted the reasons for selecting the River Tees for intensive study. These were: (1) the comparatively unpolluted condition of its head waters, (2) the inflow of a highly polluted tributary, the Skerne, at Croft, below which natural purification could be studied in a stretch of 15 miles, (3) the existence of two distinct sections of the river, one tidal and the other non-tidal, with widely different conditions in each section and (4) the heavy pollution of the tidal section by sewage and industrial wastes.

Mr. J. Longwell, in discussing the rate of decomposition of sewage in the non-tidal section below Croft from chemical and bacteriological observations covering two years, pointed out the greater rate of decomposition in summer than in winter, and stated that the breakdown of sewage could be described as occurring in a band of decomposition expanding and contracting, according to temperature, from one of only a few miles in summer to at least 15 miles in winter. It had been shown that bacterial activity preceded the decomposition of sewage in the river, indicating the biological rather than chemical nature of the natural purification process. At no time had the dissolved oxygen in the non-tidal section been low enough to harm fish, but in the Skerne, owing to sewage pollution, it was at several times entirely absent.

In discussing the flora and fauna of the non-tidal section, Dr. R. W. Butcher and Mr. F. T. K. Pentelow said that there were communities of plants and animals characteristic of foully polluted, mildly polluted and unpolluted water. These communities merged into each other according to the degree of pollution. It was shown that the distribution of certain organisms classed as "sewage fungus" was closely related to the

concentrations of organic matter and ammonium salts in the river. The direct effect on fish of sewage concentrations occurring in the Tees at Croft was negligible, but in areas of extreme pollution, as in portions of the Skerne, there were no fish of any kind. It was concluded that sewage, in the concentrations occurring in the Tees above Yarm, had a greater effect on the biology of the river from its nutritional value than it had from any direct destructive action.

Dr. B. A. Southgate described the observations made on the effects of sewage and industrial pollution in the tidal section of the Tees. The principal industrial wastes received were coke-oven effluents containing tar acids, cyanides, etc., and spent acid iron pickling liquors. Oxidation of the sewage and effluents occurred in the estuary at the expense of dissolved oxygen. Large numbers of fish were killed in the estuary. In 1930 and 1931 the death of migrating smolts was not due to oxygen deficiency, but to cyanides found in lethal concentrations. Experiments demonstrated that cyanides in coke-oven effluents can be converted into relatively non-toxic ferrocyanide by treatment of the effluents with spent pickling liquor and lime.

As regards the effects of pollution on the biology of the Tees estuary, Mr. W. B. Alexander said there was a scarcity of living organisms in the middle portion of the river, which is subject to the greatest variations in salinity due to tidal flow and to the greatest amount of pollution. In addition, organisms living on the banks must be able to withstand exposure to air at low tide and those living in the bed had to withstand the effects of sedimentation and movement of bottom deposits. It was impossible to determine to what extent the flora and fauna were affected by pollution, but it appeared that the scarcity of plant and animal life in this middle portion of the Tees estuary was not primarily due to the effects of pollution.

H. W. STREETER

Sea Outfalls

BY GEORGE W. WARR

The Surveyor, **82**, 45–6 (July 15, 1932)

This paper presented before the Conference of Engineers and Surveyors discusses the sanitary features to be considered in the disposal of sewage by means of sea outfalls.

The location of the outfall requires careful consideration of the local tides and currents based on observations over considerable periods in order that combinations of the most adverse conditions that are likely to occur may be studied. The usual method of taking such observations

is by floats placed in the water at the proposed outlet and noting their positions at suitable time intervals. The type of float found most satisfactory was a round wooden pole $1^1/_4$ inch diameter weighted so as to float upright with 6 inches exposed, the upper end painted white with a band of distinguishing color. If affected by wind, metal vanes attached to the submerged portion will increase the resistance to deflection by wind pressure. Another type of float used was one 4 feet long of cruciform cross-section made of 1 inch boards weighted at one end so that the top was just awash. Cotton reel painted in distinctive color fastened to the top by wire supports provide suitable marking.

The floats are followed in a boat and their locations determined at suitable periods by means of a sextant using a shore mark as a reference point or by taking bearings of suitable landmarks on two intersecting lines. These observations are plotted to obtain clear records of the travel under varying conditions. Such records covering complete tide cycles are useful for ascertaining the best position of the outfall and the most suitable time for discharge of sewage.

Surface float observations are sometimes desirable to learn the possible travel of floating sewage particles. Such floats should be of proper specific gravity to simulate the sewage flotsam. Slices of turnips and weighted wine bottles have been used successfully for this purpose. Examples of the vagaries of surface currents created by tidal action are given.

The method of storage and discharge of sewage at the Southwick outfall serving 18,000 population is described in some detail. Sewage is stored from 6 to 8 hours and discharge completed in about 20 minutes through an inverted syphon and 30-inch cast iron outfall 2200 feet in length. No nuisance has been experienced over a period of use of 30 years and no traces of any deposit in the surroundings of the outfall or on the foreshore are evident.

Studies by Professor D. Ellis on the dilution of sewage effected by discharge through outfall sewers are cited to support the view that, with the possible removal of coarser solids, this method of disposal is safe, sanitary and adequate. "The sterilization of sewage prior to its discharge into the sea by chlorination or otherwise appears to be an unnecessary expense, except in cases where the discharge is into an estuary or where there is danger of contaminating shellfish." Much of the floating matter may be effectually disintegrated before discharge in cases where the sewage is pumped. Purification is also expedited by this breaking up of the sewage solids. Observations of the time required for the disintegration of floating fecal matter indicated that at the end of two hours and at a distance of 4 to 5 miles out at sea the solids had broken up into such small portions as to be practically unrecognizable. J. K. HOSKINS

Improvements to an Urban Sewage Purification Works: Economic Considerations

BY H. CAMPBELL GOLDING

The Surveyor, **82**, 257-61 (September 23, 1932). Illus.

The East Grinstead sewage treatment works, remodeled some 30 years ago, consisted of antiquated screens, two sedimentation tanks with 12 hours d. w. f. capacity, five percolating filters of inadequate capacity and four one-acre beds for land treatment of sludge. The present paper outlines the studies undertaken in connection with the design of plant revisions and discusses the various features of the improved works.

Preliminary Survey and Data.—The dry weather sewage flow was determined by fill and draw measurement in the sedimentation tanks which could be completely emptied. By this method the flow was found to be 23.9 gallons per capita per day. For design purposes, 25 gal. was assumed, allowing for subsoil drainage, making a total of 225,000 g. p. d. to be provided for. Storm water flow was measured in the same way during several heavy storms, from which it was disclosed that over six times the dry weather flow was being treated at the works because of inefficient storm overflows.

Design of Purification Units

Screening Chamber.—A screening chamber housing an inclined screen with 4 sq. ft. of surface area was provided and the flowing-through velocity decreased to aid in keeping the screen clear. Screenings are drained before removal from the screening bay which is of limited size to prevent accumulations. An overflow weir is placed in the screen chamber to divert all flows in excess of three times the dry weather flow to the storm water tank. This storm flow passes through a fine screen to prevent finer solids being carried to the storm water tank.

Sedimentation Tanks.—No detritus tanks were considered necessary, though space has been provided for their future installation between the screening chamber and sedimentation tanks. These latter two tanks are of the fill and draw type and are to be increased from a total capacity of 12 hours to 15 hours dry weather flow. Distribution across the full width of the tanks is effected by a primary channel with a series of hand stops to distribute the flow leading to a secondary channel and weir leading to the tanks. The outlets will be full length overflow weirs protected by scum boards. The tank liquid will be drawn off to the sludge filters. Walls and floors are of reinforced concrete.

Storm Water Tank.—Six hours' dry weather flow storage is provided in one tank, the effluent of which will receive land treatment. Dis-

tribution of inflow is identical with that in the sedimentation tanks, although this tank will be a shallow one. The contract cost is £668.

Sludge Filters.—These six filters have a total area of 530 sq. yd., or nine persons per sq. yd. The floors are of concrete, covered with concrete aerating tiles and 10 in. of graded screened clinker. The filters will be covered with corrugated asbestos sheets of such a size as to be easily handled, and supported on I beams resting on brick piers 12 ft. apart.

Percolating Filter.—A total of 2356 cu. yd. of percolating filters will permit 95 gallons dry weather flow per cu. yd. which, although high, will from experimental evidence be sufficient, taking into consideration subsequent land treatment of the effluent. Settled sewage will be applied through traveling arms and screened before passing to the outlet nozzles. The filter walls are of the honeycomb type, 9 in. thick. Reinforced aerating tiles are to be used in the floor, covered with 6 ft. of filtering material.

Land Treatment of Effluent.—The filter effluent is to be applied to available land in the vicinity of the works by first spraying into the air and then collecting it in semicircular channels of concrete or earth laid on flat grades. These channels, of a total length of over 1700 ft. and which provide large surface area and air contact, will distribute the flow to the land through numerous shallow weirs. Handstops in the channels will direct and govern the distribution of flow on the land area.

J. K. HOSKINS

Equipment Employed in Recovering Sludge from Settling Tanks

BY EDMUND B. BESSELIEVRE

Canadian Engineer, **63**, 11 (August 2, 1932)

This paper was read by Mr. Besselievre before the meeting of the New York State Sewage Works Association at Buffalo, N. Y., June 11, 1932.

The author traces the development of sludge removal mechanisms from the days of the plain settling tank. The first power driven revolving type mechanism was installed in 1920. At present there are over 400 in use in the United States and 50 in Canada.

The advantages of mechanical equipment for removing sludge are stated to be reduced construction and operation costs (usual but not universal), lessened odor difficulties, increased sightliness, continuous removal of solids, minimum number of units, flexibility in plant location (owing to lessening or elimination of nuisance conditions) and a raising of the standards of requirements for plant operators.

Proper design of removal equipment is said to include minimization of underwater surfaces where solids will collect, motion slow enough to avoid interference with settling of solid material but fast enough to avoid septicization, elimination or reduction of underwater bearings and moving parts and construction that will reduce power requirements and repairs to minimum values. Likewise the design should be such as will effect the greatest possible concentration of solids.

The author states that sludge removal mechanisms have been in operation four or five years without interruption of service. FRANK TOLLES

Studies on Hydrogen Sulphide Formation in Sewage

BY W. RUDOLFS AND W. H. BAUMGARTNER

Ind. Eng. Chem., **24**, 1152–4 (1932)

Laboratory studies indicate that hydrogen sulphide is the chief constituent of the bad odors arising from decomposing sewage. There are four sources of sulphur in sewage:

1. Inorganic sulphur compounds present in the water supply of the community.
2. Inorganic sulphur compounds present in the ground or surface waters which find their way by infiltration into the sewer.
3. Sulphur compounds from human excreta.
4. Sulphur compounds present in industrial wastes. In general, the first and second sources are by far the most important.

The incubation of sewage under anaerobic conditions showed two distinct peaks of sulphide formation. The first rapid increase occurred after four days of incubation; the second, three days later. The proportion of combined sulphide to volatile sulphide was small throughout the course of decomposition.

Sulphur in the form of sulphate, thiosulphate and sulphite was added to different portions of sewage prior to incubation. All produced an equivalent amount of sulphide, the thiosulphate being most readily decomposed.

The effect of different cations on the decomposition of sulphates was studied by adding sodium, ammonium, calcium, magnesium and ferrous sulphates to the sewage. The sodium sulphate decomposed most rapidly during the first few days. All the salts were decomposed to the same extent in nine days with the exception of the ferrous sulphate, with which there was a decided lag. P. D. MCNAMEE

Sedimentation Experiments and Digestion Data at Saranac Lake

BY H. W. TAYLOR

Public Works, **63**, 10 (October, 1932)

The sewage treatment plant at Saranac Lake consists of three settling tanks equipped with parallel sludge collectors, a sludge digestion tank, sludge storage tank and sludge beds. The plant was put into operation December 9, 1931, and treats sewage from a population of 10,000.

Before the plant was put into regular operation one of the settling tanks was used for experiments and tests relating to the operation and characteristics of the sludge collectors and to the deposition of fresh sludge in a flat-bottom tank.

Each tank is 75 ft. long, 16 ft. wide and has an average depth of 7 ft., giving a total detention period of 3.25 hours. Trial tests showed that if the conveyor was operated for one-half revolution twice a day, the resultant sludge removal was satisfactory. There seemed to be no practical gain in a continuous operation of the collector.

Experiments were conducted to determine the amounts of fresh sludge deposited in different parts of one of the tanks operated under normal conditions but at velocities ranging from 0.09 inch to 0.376 in. per second. Averaging all the experiments, it was found that over 30 per cent of the total sludge deposition took place in the first 10 per cent of the length, 50 per cent in the first 35 per cent of the length, 78 per cent in the first 50 per cent of the length and 90 per cent within 70 per cent of the length. The figures indicate that the conveyor could, if so desired, be placed so that from one-third to one-half of the sludge deposition would occur directly into sludge pockets and not have to be moved by the conveyor.

The sludge from the settling tanks is pumped to one of two sludge tanks, one of which, used as a digestion tank, is 30 ft. in diameter and has a capacity of 14,000 cu. ft., providing 40 days storage for 14,000 people at the rate of 25 cu. ft. of fresh sludge per 1000 people per day. This tank is heated and equipped with a Downes cover.

A chart accompanies the article showing the relationship between the temperature and the gas production for the period of February 1, 1932, to August 18, 1932. The gas production was only 7100 cu. ft. in February but increased rapidly and reached a maximum of 293,000 in June, falling to 280,100 in July, or 0.9 cu. ft. per capita per day, and increasing to 1.27 cu. ft. for the first nine days of August. Delayed digestion during the first two or three months was undoubtedly responsible for the excessive gas production of June and July. It is expected, however, that the final rate will be above the customary 0.6 to 0.7.

Periodically "yellow" sludge collects under the cover to a depth of 1 to 4 ft., chills and becomes inactive. The heating coils fail to heat this sludge, thus allowing a large volume of material containing grease and fat, which is a potential gas producer, to remain inactive. The only method of liquefying and warming the floating sludge is by "jetting" and hosing. A permanent "jetter" has been installed to overcome this difficulty. "Jetting" this floating sludge was continued during April; the temperature increased and it became gas-producing.

In August considerable volume of wet and uncompacted floating yellow sludge still remained and the practice was established of mixing small quantities of this with seeding sludge from the bottom and supernatant liquor and pumping it back to the digestion tank through the fresh sludge inlets. This floating sludge is a long way from heavy seeding material, and this procedure is the simplest method of seeding it and changing its location in the tank.

Fresh sludge has been constantly pumped to the sludge digestion tank since the 20th of December, 1931, the supernatant liquor being withdrawn, prior to digested sludge withdrawal to make room for fresh sludge.

The fresh sludge withdrawn daily is equal to 430 cu. ft. a day from an estimated population of 10,000 people. Regardless of this apparently large per capita figure, the sludge withdrawn from the settling hoppers is unusually free of "free water." C. T. WRIGHT

Automatically Proportioning Ferric Chloride to Sludge

Public Works, **63**, 35 (October, 1932)

The Chicago Sanitary District, in their West Side Experimental plant, will use ferric chloride for conditioning the sludge for filtering and drying. The efficacy of this method depends upon the accuracy with which small percentages of the reagent can be proportioned to the changes in the quantity of the sludge, and on a convenient means of adjusting the feed to compensate for variations in the character of the sludge.

Special equipment was built for handling the addition of ferric chloride. This equipment was connected by texrope and pulley drive to a variable speed shaft driving the Dorrco sludge pump. It thus is kept in step with changes in the rate of flow of the sludge. A gear reducer slows down the drive to a practical pumping speed. The reducer unit drives an eccentric and connecting rod, which flexes a rubber diaphragm pump at a rate proportionate to the sludge flow. The diaphragm, casing, special check valves, reagent piping and all other parts which are in contact with reagent are of rubber, hard or soft, due to the corrosive properties of ferric chloride.

The diaphragm is 6 inches in diameter, feeding from 2 gallons a minute down to practically nothing and its adjustment lies in the arrangement for shortening the stroke. Although the machine automatically compensates for sludge flow changes, the operator can, even during high speed operation, adjust for minute changes in the ferric-chloride feed to maintain constant pH readings. C. T. WRIGHT

Developments in Sewage Treatment with Ferric Chloride

BY R. W. CLARK

Public Works, **63**, 21 (October, 1932)

The use of ferric chloride for conditioning excess activated sludge before application to mechanical filters has been tested at Milwaukee, Indianapolis and Chicago, where uniformly good results have been maintained under actual operating conditions. Experiments at Columbus, Ohio, and Baltimore, Maryland, show that digested sludge can be prepared for mechanical drying even more economically than can excess activated sludge.

With sand drying beds also a great improvement in the drying quality of sludge is obtainable by treatment with ferric chloride. It has been demonstrated that excess activated sludge can be dried rapidly (sometimes within two or three days) on sand beds, when treated with a coagulant. Hydrogen-ion control is generally accepted in the treatment of excess activated sludge, the practice being to add ferric chloride in sufficient quantities to maintain a pH of about 3.7. On the basis of active $FeCl_3$ to the dry solids treated, the resulting ratio is approximately 8 per cent, although the figure may vary from 5 to 12 per cent depending upon various factors. For digested sludge there is some question among experimenters of the advantage of definite pH control.

Although chemical precipitation of sewage solids has had a rather unsatisfactory history in the past, it is finding more general acceptance today owing solely to an appreciation of the effects of various chemicals, the use of definite control such as pH or turbidity measurements, and the utilization of mechanical equipment for mixing and flocculation.

The chemical precipitation process is subject to exact control and can be used to deal with seasonal and daily fluctuations in organic load, inexpensively and effectively. The process is of particular interest at plants which receive industrial sewage such as cannery, packing-house or other trade wastes. Such loads are seasonal and cause aggravating upsets in biological treatment methods, especially when acid conditions

exist. An advantage in ferric chloride is that coagulation can be secured with either acid or alkaline reactions, and the use of lime to correct sewage acidity might assist flocculation and decrease the amount of coagulant needed.

Ferric chloride has been used successfully to effect a high removal of solids from concentrated sewage such as packinghouse wastes containing as high as 500 p. p. m. of suspended solids and a B. O. D. of about 2000. It seems to be most effective when the sewage contains a relatively high percentage of colloidal matter and when it reaches the plant in a reasonably fresh condition.

The possibilities of chemical and mechanical methods as the sole process of treatment are sufficiently attractive and promising to invite further trial on a larger scale. C. T. WRIGHT

Sewage Disposal Plant at Brampton, Ontario

BY W. M. TREADGOLD, Consulting Engineer, Toronto

Canadian Engineer, **62**, 19 (June 28, 1932)

Sewage treatment at Brampton, Ont., was provided by a septic tank built in 1906. In 1917, half of the original plant was converted to the activated-sludge process. In 1931–32 a new activated-sludge plant was built at a new location. Characteristics of the new plant are as follows:

Capacity	1 m. g. d. Present flow $^1/_2$ m. g. d. from 500,000 people.
Sewage	Domestic with tannery, paper and creamery wastes.
Bar Screens	$^3/_4$-inch openings, 3 ft. wide mechanically cleaned (Hankin).
Grit Chambers	2, each 40 ft. × 6 ft. wide × 3 ft. deep, hand cleaned.
Aeration Tanks	2, each of 3 passes about 40 ft. long × 10 ft. wide × $9^1/_2$ ft. water depth, 1 row diffuser plates.
Sludge Settling Tanks	2 Dorr Clarifiers, each 28 ft. square × 9 ft. water depth.
Re-aeration Channels	2, each about 80 ft. long × 6 ft. wide × 9 ft. water depth with air lifts.
Digestion Tank	Dorr type 30 ft. diameter × 16 ft. deep.
Sludge Drying Beds	36 ft. × 72 ft. glass covered.
Power House	30 ft. × 37 ft.
Power Plant	2 Babcock-Wilcox and Goldie-McCulloch, 600 ft. vertical compressors at $5^1/_2$ lbs. with 30 hp. electric motors. 1 Barnes 75 g. p. m. sludge pump. 1 Spencer water heater for coal and gas.

The article makes mention of heat for the sludge beds. Gas is produced at the rate of about $^1/_2$ cubic foot per capita daily. Digester temperature is maintained at 75° F. Lime has been added to obtain a pH in the sludge of from 7.2 to 7.8.

The approximate cost is given thus,

General Contract	$29,000.00
Mechanical Equipment	14,500.00
Compressors	5,000.00
Piping and Valves	5,000.00
Diffuser Plates and Connections	2,500.00
Electric Wiring and Conduit	1,100.00
Heating and Plumbing	3,000.00
Sludge Bed Cover	2,700.00
Total	$62,800.00

FRANK TOLLES

Urbana and Champaign (Illinois), Sanitary District Sixth Report, from May 1, 1931, to April 30, 1932

BY GUS RADEBAUGH, Superintendent

In the introduction Harry F. Ferguson, Chief Engineer of the Illinois State Department of Health, gives an outline of the growth of sewage treatment works in Illinois. At present there are 653,000 people in Illinois living in sanitary districts, not including the Sanitary District of Chicago and the North Shore Sanitary District. Most of these districts have efficient sewage treatment works and the sewage from over 80 per cent of the population served by treatment works has complete treatment.

The sewage from the Urbana and Champaign Sanitary District is treated by the Imhoff-tank and trickling-filter method. After passing through the secondary settling tank, the plant effluent passes through a lagoon and thence to the Salt Fork Creek. The plant has been in continuous operation since November, 1924. During the last year the total cost of treatment was $1.54 per capita, which included 36 cents per capita for operation. The figures are evidently based on the total population of the sanitary district and not the population served by the treatment works.

Figures showing the past growth and probable future growth of the cities of Champaign and Urbana and of the University of Illinois are given. The design estimates made in 1922 agree reasonably well with the 1930 census and student enrollment at the University. Although a separate system of sewers is in use, there is enough leakage to cause the daily average sewage flow to vary between 130 gallons per capita for a wet year and 90 gallons per capita for a dry year. Plots are given to show the relation between rainfall and sewage flow.

FIG. 1.—Sludge Beds Enveloped in Plantings of Flowers and Shrubs.

FIG. 2.—Final Unit of Treatment Nestled Among Trees, Shrubs and Flowers.

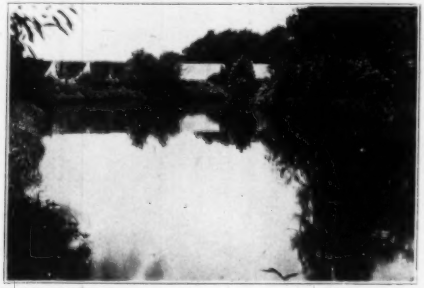

FIG. 3.—The Lagoon. A Stand-by Unit Receiving Flow from Final Unit of Treatment.

LAGOON
RECEIVED CLARIFIED SEWAGE FROM SECONDARY SETTLING TANK
SUNFISH CARP AND CATFISH LIVING IN THIS POND IN WATER THAT WAS FORMERLY SEWAGE
FIRST DATE OF PLANTING FISH NOVEMBER 1929

FIG. 4.—Method Used to Impress the Public About Fish Propagation in the Treated Sewage.

ATTRACTIVE FEATURES OF THE URBANA-CHAMPAIGN TREATMENT WORKS.

During the fiscal year, May 1, 1931, to May 1, 1932, the sewage treated averaged 2.9 m. g. d. for an estimated connected population of 35,000. The yearly averages for the B. O. D.'s in p. p. m. were: raw sewage 295, Imhoff effluent 176, trickling filter effluent 22, secondary settling tank effluent 13.9, lagoon effluent 7.1. The figures for suspended matter were: raw sewage 215, Imhoff effluent 88, trickling filter effluent 53 and secondary settling tank effluent 37 p. p. m. From a total of 1059 m. g. of sewage treated during the year there was removed 39 cu. yd. of screenings, and 21 cu. yd. of grit. One thousand three hundred and eighty cu. yd. of sludge and 870 cu. yd. of scum were dried on the sand beds. The scum was removed from the gas vents by an electrically driven diaphragm pump. This procedure is working out satisfactorily. Dried sludge was removed by farmers. Thirty-eight hundred pounds of lime were used in the Imhoff tanks for pH control during the year. There was no trouble from flies on the trickling filter. Fish seeded in the lagoon in 1929 are thriving. An analysis of the effluent to the lagoon gave zero *B. coli*. Analyses of the water of Salt Fork Creek above and below the plant gave only a slight increase in the yearly average B. O. D.—5.4 to 5.6 p. p. m. A novel feature of the report is the tabulation of operating results and analytical data on a durable linen insert.

Several improvements were made during the year, including a cover on the dosing tank, an extension to the pump house and the construction of a lagoon for sludge storage with an area of approximately 15,000 sq. ft.

R. J. BUSHEE

West Riding of Yorkshire Rivers Board, Thirty-ninth Annual Report, April 1, 1931, to March 31, 1932

BY JOHN H. GARNER

The work of the Rivers Board for the year consisted of (1) inspections and surveys of industries reported to be discharging solid or liquid wastes into streams, (2) application to the Ministry of Health for consent to take legal proceedings against firms and urban districts against discharging polluting wastes to the streams, (3) assistance in prosecutions by fishery boards for pollution resulting in destruction of fish, (4) analysis of samples of water for the Wakefield Corporation, (5) laboratory chemical analyses of samples relating to sewage purification works, manufactories, stream waters and miscellaneous, (6) gauging of rivers, and rainfall records, (7) special studies and reports on beet sugar, gas and miscellaneous wastes.

In most cases corrective measures against pollution by various trades

wastes were either taken or proposed so that no legal proceedings were necessary. A local legal inquiry will be held in the case of a paper mill discharging sludge in the Saddleworth District.

Analyses were made of river samples taken throughout West Riding in special chemical surveys of the Rivers Aire and Ouse. At points of sampling where the river was devoid of oxygen a few years ago, the dissolved oxygen content reaches as much as 70 to 75 per cent of saturation at present.

Sewerage and Sewage Disposal.—There are at present 431 works in operation, 24 new works or extensions in progress, 20 schemes sanctioned and 24 schemes before the Ministry of Health. Due to recent measures to effect national and local economy the total amount of loans for which sanction was applied for amounts to £93,469, which compares with £600,000 per annum for the past 5 years.

The status of the sewage treatment works of the County Boroughs and grouped by catchment areas in the West Riding are briefly outlined. A number of new plants and many extensions and improvements in existing plants have been made to meet the needs of the various districts. In general, contact beds are being replaced by percolating filters, bio-aeration plants are being installed or enlarged and storm water tanks are being extended. In most cases where either bio-aeration tanks or percolating filters of sufficient capacity are available good effluents are reported. A number of "Simplex" activated sludge units are in use.

Some of the larger installations mentioned are Bradford, Sandall, Leeds, Halifax, Huddersfield, Sheffield and Knaresborough.

By-products plants for recovery of grease by the solvent extraction method are in satisfactory operation at Bradford, Huddersfield and Halifax.

Studies on the digestion of sludge have been made and are being carried further by a research committee with John Haworth, Chairman.

Trade Refuse Purification.—There are about 2000 trade premises in the West Riding, of which 900 have treatment works and the remainder are connected to sewers. The greatest volume of wastes comes from the textile industry. These wastes, mixed with sewage, can now be treated without difficulty, except that changes in manufacture give new problems requiring modification of treatment works.

The treatment of textile waste liquids from Woolcombers, Limited, at Lower Holme Shed has been of interest. By a process of evaporation, centrifuging and incineration, the waste liquid is made to yield distilled water, lanolin and potash. The distilled water and potash is re-used for scouring raw wool and the lanolin is available for sale.

The cuprammonium process which is used at the artificial silk factory of British Bemberg, Ltd., at Wheatley is dependent economically on recovery and re-use of expensive chemicals. Only wash waters are there-

fore discharged, which are settled in large ponds having a capacity of 2 million gallons, equal to the daily flow from the plant.

The beet sugar factory at Poppleton was operated for 32 days in 1931. During this time 39,148 tons of beets were sliced at the rate of 1223 to 1679 tons per day. The effluent discharged amounted to nearly 4.5 m. g. d. Treatment consisted of passing through grit chambers, with mechanical elevators and screen and settling ponds where 90 per cent of the suspended matter was removed.

The mining and coking industry was also responsible for a great deal of pollution in the West Riding. The need for cleaning coal has become important and the number of coal washeries has increased. Pollution by coal washing waters is generally due to inefficient operation, mechanical breakdown of pumps or insufficient capacities of settling tanks.

It is not profitable to produce ammonium sulphate from crude gas liquor, since ammonia can be made very cheaply from atmospheric nitrogen. The disposal of the gas liquor has become a problem. In some cases arrangements for discharge to local sewers have been made, but adequate dilution by uniform flow of these liquors must be maintained because sudden discharges interfere seriously with the sewage purification processes.

A suitable layout for a plant to handle gas liquors before being discharged to the sewer consists of a rough settling chamber followed by an underground settling tank of 100,000 gal. capacity, sufficient to store for 365 days the waste produced in 153 days. Before being discharged to the sewer the liquor passes through another settling tank which has 5500 gal. capacity, which provides further settling and insures a constant feed through one of two orifices allowing 55 and 100 gallons of liquid per hour to flow to the sewer.

At Bornoldswick the gas liquor is passed through a coarse filter of graded coke followed by fine coke breeze, which removes all traces of tar. Both filters have downward flow and standpipe overflows, and clear liquor is discharged to the sewer from the top at a regulated rate.

At Bingley the volume of gas liquor is 1000 gallons per day and the dry weather sewage amounts to 1,000,000 gallons per day. The tar is removed by filtering through wood wool. The liquor is fed at the bottom of the filter and the clear liquor discharged to the sewer from the top. Tar is drawn off periodically at the bottom. No difficulty is encountered if the flow of gas liquor is carefully regulated.

In some cases attempts have been made to dispose of the liquor by evaporation. A limited quantity can be disposed of by evaporation on the bars of the gas plant producers. A separate evaporator has been installed at the Harrogate Gas Company. The liquor is settled, pre-heated and then passes to an evaporator. The vapors are piped to the boiler

flues. The concentrated liquids are viscous enough to be mixed and burned with the other fuel. S. I. ZACK

Seventeenth Annual Report of the Bureau of Sewage Disposal, City of Schenectady, New York, 1931

BY MORRIS M. COHN

An average flow of 8.48 m. g. d. was treated at the plant. The screenings removed by the bar screens amounted to 1.3 cu. ft. per m. g. It was found that trenched screenings required 3 years to be decomposed in the wet clay soil. More rapid decomposition was obtained by plowing.

The averages of suspended solids, B. O. D. and nitrates are summarized as follows:

	Parts per Million		Per Cent Removal Based on Raw Sewage	
	Suspended Solids	B. O. D.	Suspended Solids	B. O. D.
Raw Sewage	182	103	..	..
Imhoff Effluent	60	76	67.2	25.2
Filter Effluent*	53	15	70.8	85.4

* Nitrites and Nitrates averaged 5.6 p. p. m.

The sludge drawn averaged 94.54 per cent moisture, 65.91 volatile, pH 6.7 and specific gravity of 1.009. Frequent hosing of scum was practised. When sludge was drawn without recourse to hosing, lower moistures were obtained. A total of 14,615 cu. yd. of wet sludge was drawn from the Imhoff tanks of which 9840 cu. yd. went to the beds and the balance to lagoons. The beds were dosed to a depth of 10 in. and produced a dry cake $3\frac{1}{2}$ in. thick. A total of 2850 cu. yd. dry sludge was removed. The beds were dosed 8.9 times per year. The income from sale of sludge was $160. Lagooned sludge dried at the surface. New sludge was pumped under the dry blanket and excess liquor drawn off after the sludge became gas lifted.

The filters were operated under adverse conditions due to submergence of the underdrains by high river stages.

Besides the usual flooding for fly control, an original method of auxiliary control was devised consisting of a portable torch which developed a flame of 2000° F. Flies roosting on gallery walls, stair enclosures and tall grass around the filter were destroyed by flaming.

There are about 3 acres of filters at Schenectady and there are no final settling tanks. S. I. ZACK

Annual Report of the Superintendent of Sewers of the City of Worcester, Mass., for the Year Ending Nov. 30, 1931

By JOHN H. BROOKS, JR.

The operation of the treatment plant continued in a satisfactory manner during 1931. A reduction in the amount of suspended matter and iron content of the raw sewage and dry weather flow has been noted, which is attributed to the conditions during the industrial depression. The average flow treated was 19.63 m. g. d. contributed by an estimated population of 190,000. The new mechanically raked Evers-Sauvage bar screen with $1^1/_4$-inch openings has been effective in keeping rags out of the Imhoff tanks. Alterations in the bottom of the grit chambers have made possible a more complete flushing and cleaning of the grit chambers each month. Plans and construction are under way to use the old intermittent sand filters for lagooning of sludge in winter.

This report contains tabulations of monthly averages, maximums and minimums of rainfall, temperature, data on grit, screenings, Imhoff and trickling filter operation and chemical analyses, and division of costs of treatment plant operation.

The annual averages of suspended solids and B. O. D. and per cents removal for 1931 are summarized as follows:

	Results in P. p. m.		Per Cent Reduction Based on Raw Sewage	
	Suspended Solids	5 Day B. O. D. 20° C.	Suspended Solids	B. O. D.
Raw Sewage	229	196	..	..
Imhoff Effluent	101	137	56	30
Trickling Filter	140	30	..	..
Final Effluent*	64	22	72	89

* Nitrogen as Nitrites and Nitrates 11 p. p. m.

Quantities of grit, screenings removed and grease skimmed were 4.56, 2.50 and 0.73 cu. ft. per m. g. d.

The average sedimentation period in the Imhoff tanks was 3.0 hours. Sewage was dosed on the trickling filters at the rate of 1.39 m. g. a. d.

Sludge removed from the Imhoff tanks contained 6.78 per cent dry solids, of which 49.7 per cent was volatile and 4.69 per cent iron. The specific gravity of the sludge was 1.033. The total amount of dry solids in the sludge was 4108 tons. A total of 13,241 cu. yd. of dried sludge was taken off the beds by a Barber-Greene loader, also by forking and horse-drawn tip carts, and disposed of on a dump adjacent to the drying beds.

The total cost of sewage treatment is reported to be $8.20 per million gallons, excluding interest and depreciation. S. I. ZACK

Sewage Research at Manchester
Annual Report of the Rivers Department, City of Manchester, for the Year Ending March 31, 1932

BY EDWARD ARDERN AND W. T. LOCKETT

Laboratory Experiments

Laboratory experiments were made with regard to the separate digestion at 26° C. of the three common components of sewage sludge, namely, paper, grease and fecal matter. The results obtained were compared with previous results at 50–55° C.

Samples of the paper, grease and fecal matter, of an amount necessary to provide 1.5 grams of dry organic matter, were placed in separate flasks; and to each sample there was added well-digested sludge, of 94–95 per cent moisture, equivalent to 1.5 grams of dry organic matter. These flasks, together with one containing only well-digested sludge, were placed in a water bath and the gas produced was measured daily by collecting it in cylinders over brine saturated with CO_2. The volume of gas produced by the digested sludge alone was subtracted from that produced by each of the others, and the results were calculated to a basis of one gram of dry organic matter.

The crude sludge produced the most gas, a total of 620 cc., at a very uniform rate, for the first twelve days, and at a somewhat slower subsequent rate, the total for eighteen days being 770 cc. The paper gave very little gas for the first two days. From the second day to the tenth day the gas production proceeded at a uniform rate to give a total of 430 cc., and thence much more slowly to give a total of 490 cc. in eighteen days. The fecal matter produced gas fairly uniformly, with a total of 320 cc. in twelve days, and at a slower rate to give 350 cc. in eighteen days.

Curves show the gas production for the first 10 days of these materials at 50–55° C., other conditions being the same. The curve obtained with crude grease was similar to that obtained at the lower temperature, except that the gas production was about doubled, 980 cc. in ten days as against 500 cc. in the same time at 25–30° C. From the paper at 50–55° C., after a one day pause, a total of 580 cc. of gas was produced in three days and 700 cc. in ten days. From the fecal matter, 340 cc. of gas was obtained in four days and 420 cc. in ten days. The striking thing was the very rapid digestion of the paper at 50–55° C., the digestion being practically complete in three or four days. The author suggests that the divergent results obtained by different experimenters in thermophilic digestion may be due to the difference in the sludges as regards the proportion of cellulosic material present.

Demonstration Sludge Digestion Plant

This plant consists of two digestion tanks, each of 3220 gallons capacity, fitted with a hot water circulating system, thermostatic controls, etc., to allow the digestion of sludge in the one case at 25–30° C. and in the other at 50–55° C. Tests were carried out on a mixed sludge, of six parts fresh sludge to one part activated sludge based upon the dry organic matter content of the sludges, and also on activated sludge alone.

Before sludge was added a sufficient quantity of digested sludge or supernatant water was withdrawn from the tank to give the necessary space. The sludge to be added to the tank was heated to the required temperature, mixed with a small amount of digested sludge, and sprayed over the surface of the tank by means of a splash plate. The upper surface of the tank was then stirred by hand and by a pump to obtain good mixing. Occasionally, the entire contents of the tank were thoroughly mixed by pumping for not less than an hour. This was to obtain a good sample of the contents of the tank. Measurements and analyses were made of the sludge added, and of the sludge, water and gas withdrawn.

Digestion of Mixed Sludges at 25–30° C.—The "seeder" for the tests with "mixed" sludge was from the previous batch operations. At the start, small volumes of sludge were added daily except on Sunday. The amount of sludge added was increased daily as the results warranted, and eventually a seven-day week was adopted. For the digestion at 25–30° C. the best results with the "mixed" sludge were obtained during a 22-day run in November and December, 1931. The sludge dealt with had an average water content of 93.2 per cent. This was equal to a detention period of 23.6 days for a sludge of 90 per cent water, or 13.6 days for a sludge of 92 per cent water, after making allowance for the redigestion of the partially digested sludge in the supernatant liquor withdrawn.

The gas yield was 3.8 cu. ft. per pound of dry organic material added. Attempts to increase the amount of sludge dealt with gave a fall in gas yield, a lowering of the pH value of the sludge in the chamber and difficulty in obtaining a supernatant liquor of low solids content. It is believed, however, that the above-mentioned results could be maintained when digesting normal mixed sludge. The results as compared with batch digestion are to be preferred because of: (*a*) greater ease of manipulation, (*b*) more rapid digestion requiring less digestion tank capacity and (*c*) more regular evolution of gas. There was considerable difficulty in obtaining a supernatant water relatively free from undigested sludge. The water withdrawn will either have to be added to the raw sewage at the plant inlet, or means adopted for concentrating this undigested sludge and returning it to the digestion tank.

Laboratory experiments have been made on two-stage digestion from

which it appears that there can be obtained: (1) a better quality of supernatant water, (2) a more thoroughly digested and less bulky sludge and (3) a reduction in the detention period in the heated tanks.

Digestion of Mixed Sludge at 50–55° C.—The best results were obtained from a 41-day run, during which wet sludge containing 93.7 per cent water was dealt with. The detention period was equivalent to 23.0 days for a sludge of 90 per cent water, or 13.3 days for a sludge of 94 per cent water after making allowance for the redigestion of the sludge withdrawn with the water. The gas yield was 3.53 cu. ft. per pound of dry organic matter. The supernatant water withdrawn contained much less undigested sludge than in the case of the digestion at 25–30° C. The author concludes that for the sludge obtained at Davyhulme, the results do not warrant the added expense of thermophilic digestion. He concludes that a tank capacity equal to 14 days input of sludge, containing approximately 94 per cent water, would be adequate to treat the mixed sludge from Davyhulme at 25–30° C.

Digestion of Activated Sludge at 25–30° C.—By decanting, an activated sludge of 97.5 to 98.25 per cent water was obtained, which is about as dense an activated sludge as could be had in practice by simple sedimentation. This was added to the digestion tank after a suitable "seeder" had been built up. Considerable difficulty was met with at the start because of the large amount of organic matter withdrawn with the supernatant liquid. This caused such a loss of the seeding material as to interfere seriously with the digestion. The difficulty was overcome by allowing the liquid to settle for 18–20 hours in a tank and returning the deposited sludge with the incoming fresh sludge. A typical trial run of 23 days, with a fresh sludge of 97.43 per cent moisture added, gave 3.83 cu. ft. of gas per pound of dry organic material added to the tank, and the water decanted had a solids content of 0.31 per cent. This is equivalent to a detention period of 13.8 days, which would correspond to 10.7 days calculated on the basis of a sludge containing 98 per cent water. The organic material was 69.0 per cent of the dry solids of the sludge added, and 53.9 per cent of the dry solids of the digested sludge.

Digestion of Activated Sludge at 50–55° C.—At 50–55° C. there was less trouble in obtaining a satisfactory supernatant liquid, but in the later runs it was settled for 18–20 hours and the deposited sludge returned to the tank. Results for several typical tests are given. The results for the test with the shortest detention period, with an incoming sludge of 97.36 per cent water, gave 4.01 cu. ft. of gas per pound of dry organic matter. The reduction of the organic matter content, on a dry basis, was from 69.67 per cent in the incoming sludge to 61.84 per cent in the digested sludge. The detention period was 6.3 days, corresponding to

4.8 days for a sludge of 98 per cent water. The solids content of the water withdrawn was 0.88 per cent.

Concentration of Digested Activated Sludge

Laboratory experiments were made to determine the reduction in volume of the digested activated sludge on standing at atmospheric temperature. For a sludge digested at 25–30° C., the volume of the digested sludge was reduced by 50 per cent on standing ten to twenty days. This is equivalent to a total reduction of 78 per cent of the volume of the fresh activated sludge. For the sludge digested at 50–55° C., the volume was reduced 30 per cent on standing two days, corresponding to a total reduction of volume of the fresh activated sludge by 78 per cent. After standing ten days the volume of the digested sludge was reduced by 50 per cent, and the total reduction of volume from the fresh sludge was 84 per cent.

Discussion

Contrary to the results obtained with the "mixed" sludge, the activated sludge gave a much faster digestion at 50–55° C. than was obtained at 25–30° C. The authors attribute this to: (*a*) a better separation of the activated sludge from the water at the higher temperature and, consequently, less loss of "seeder" material with the water withdrawn, (*b*) more pronounced ammoniacal fermentation and so a higher pH value in the digestion tanks and (*c*) a lower percentage of grease in the activated sludge than in the "mixed" sludge. The principal difficulty both with the digestion and the subsequent drying on sand beds of activated sludge alone is due to the large volume of water to be dealt with. It has not been demonstrated that sufficient gas would be obtained to maintain the digestion of activated sludge at 25–30° C., much less at 50–55° C. Subsequent experiments will deal with concentration of the sludge by mechanical means before digestion, and with the addition of certain portions of settled sludge to the digestion tanks.

R. J. BUSHEE

Sewage Treatment Project—Cleveland

BY GEORGE B. GASCOIGNE

Water Works and Sewerage, **79**, 121–3 (April, 1932)

The City of Cleveland is now constructing new sewage plants and enlarging old ones.

The Easterly plant is now being built. It consists of bar gratings, grit chambers, pre-settling tanks, aeration tanks, sludge settling tanks, power house and administration building. At present it is proposed to pump

the sludge from the primary and secondary processes 13 miles to the Southerly plant where it will probably be digested and run onto covered sand beds for drying.

The plant is designed to serve a population of 770,000 with a dry weather flow of 123 m. g. d. Ultimately the plant can be enlarged to care for 1,000,000 people.

The grease catchers and pre-settling tanks will be able to treat all sewage and storm water flows up to $2^1/_2$ times the dry weather flow. Aeration and sludge settling tanks can treat $1^1/_2$ times the dry weather flow.

The aeration and sludge settling tanks will be grouped into four major batteries, which can be operated jointly or independently. The aeration tanks will be built in two passes, each 27 feet wide and water depth of 15 feet. The length of horizontal travel of sewage will be 670 feet. Aeration and agitation of the sewage is by means of porous plates set in aluminum containers, with the spiral flow type of design. The aeration period will be 5 hours, based on 125 per cent rated capacity, with 25 per cent returned sludge.

The sludge settling tanks are circular in plan, 112 feet in diameter and with a side water depth of 12 feet. They are Dorr equipped. Detention period is $2^1/_2$ hours for the dry weather flow increased by 25 per cent for returned sludge.

The estimated cost for the Easterly project is $12,000,000, and the annual cost of operation is estimated at $600,000 as of the year 1940.

The Westerly works placed in operation in 1921 are to be enlarged.

The work is being planned so that by the end of the year 1935, the sewage from the Easterly District will receive 92 per cent treatment; that from the Southerly District, 85 per cent; and at present that from the Westerly District, 35 per cent treatment. H. GLADYS SWOPE

Correction

Line 29, page 567, of the abstract in the May, 1932, issue, referring to the Tenafly, N. J., plant should be changed from "obtain a pH of 6.6 to 6.8 for at least a 4-hour period" to "maintain at the effluent of the tank a reaction of pH 8.6 to 8.8 and to continue this for at least 4 to 6 hours."

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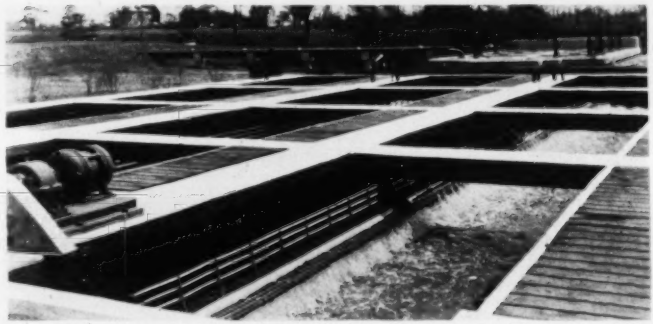

For this sewage treatment plant, Barrington, N. J. (Remington, Vosbury & Goff, Consulting Engineers), Link-Belt Company furnished Straightline Collectors for the primary and final settling tanks, and Straightline Aerators for tanks which are each 12½ ft. wide, 12 ft. deep and 60 ft. long. At this plant the b.o.d. of the influent averages 500 p.p.m., and that of the effluent does not exceed 11 p.p.m.

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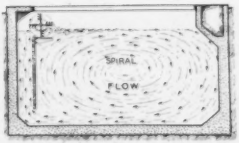

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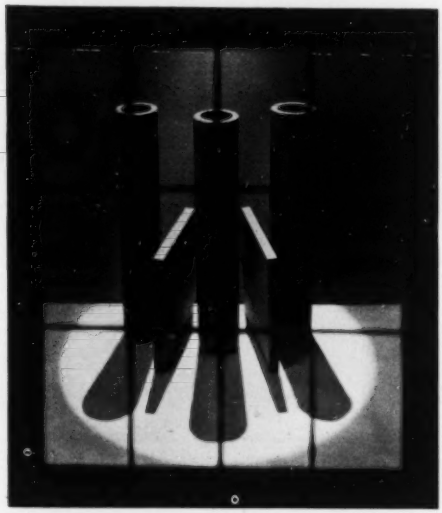

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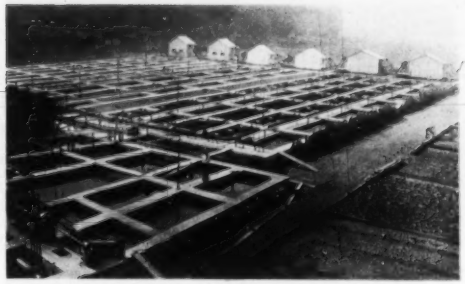

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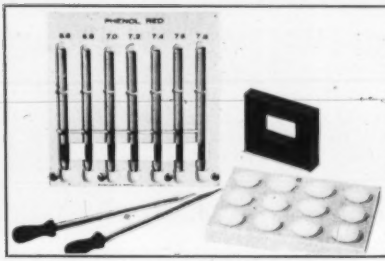

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Statement of the Ownership, Management, Circulation, etc., Required by the Act of Congress of August 24, 1912, of Sewage Works Journal, published bimonthly at Easton, Pa., for October 1, 1932.

State of New York }
County of New York } ss.

Before me, a Notary Public in and for the State and County aforesaid, personally appeared William W. Buffum, who, having been duly sworn according to law, deposes and says that he is the Business Manager of the Sewage Works Journal and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor and business managers are:

Name of — Post Office Address

Publisher, Federation of Sewage Works Associations, c/o H. E. Moses, Pa. State Dept. of Health, Harrisburg, Pa.

Editor, F. W. Mohlman, 845 South Wabash Avenue, Chicago, Ill.

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WM. W. BUFFUM, Business Manager

Sworn to and subscribed before me this 16th day of September, 1932.

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(My commission expires March 30, 1934)